HABITAT USE, GROWTH, AND FEEDING OF LARVAL ALEWIFE IN A SHALLOW RIVER MARGIN OF THE UPPER HUDSON RIVER

A Thesis

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ABSTRACT

The upper third of the Hudson River has experienced thousands of hectares of shallow water habitat loss from filling shallow, low-velocity areas along the margins of the river with dredge material from channelization. Such low-velocity habitats often support high larval fish densities and serve as nursery habitat for many early life fishes. Moreover, the anadromous alewife populations along the Atlantic coast are in decline, including the Hudson River population. Early life is a defining stage in the life history of many fish species, with the relative abundance of populations being defined in the first few weeks of life. Therefore, the rehabilitation of previously filled nursery habitat for alewife and other Hudson River alosines could aid in the recovery of these species.

This study considered larval fish presence in the context of different physiochemical parameters of shallow water microhabitats. Particular emphasis was placed on the distribution and ontogeny of larval alewife to inform habitat rehabilitation for this species. In order to sample in shallow areas as well as maintain the contrasts of intra-site variability, larvae were collected by random point abundance sampling using a throw trap within three shallow water sites in the Tivoli Bays Estuarine Research Reserve.

Chapter 1 examined larval alewife distribution in relation to microhabitat structure using a logistic mixed effects model. Results indicated that alewives were more frequently present in lower velocity and deeper water while avoiding aquatic vegetation. Furthermore, larvae were caught more frequently during ebb tide and at low river water levels. These findings suggest that considerable local variation occurs within nursery habitat and that this variability affects habitat suitability.

Chapter 2 examined the shift in habitat use and feeding of alewife over the larval period. Ontogenetic changes begin in the embryo and continue after hatching so that additional

physiological and behavioral capabilities increase with age. A linear model was developed to explore the relationship between fish size and a variety of habitat and biological community metrics, including available habitat, degree-days, larval density, and feeding incidence. Furthermore, larval diets were examined to identify feeding shifts over larval ontogeny. Distinct shifts in habitat association and diet were found in feeding larvae. Larger fish were found at locations with deeper water and higher water velocity. Alewives fed on microzooplankton when first feeding and shifted to progressively larger prey organisms as they grow.

The appendix characterized alewife habitat partitioning with the rest of the shallow water fish community using canonical correspondence analysis. Several differences in habitat use were found between and among larvae and adult fishes of the Tivoli Bays community. The most important environmental variables influencing the fish assemblage were depth, dissolved oxygen, distance from shore, substrate, temperature, and vegetation density (*Trapa natans* and *Vallisneria americana*). All groups of larvae and adults displayed unique environmental signatures, including the larval and mature tessellated darters (Percidae).

The observed shifts in microhabitat association and prey choice for larval alewife and habitat partitioning of the fish community have implications for rehabilitating suitable nursery habitats. Both active orientations to structural habitat components as well as tidal transport mechanisms are suspected to influence intra-site distribution. Restoration plans targeting larval alewife should take into account this intra-habitat variation. Furthermore, rehabilitation should include micro-scale heterogeneity to accommodate the range of ontogenetic habitat associations of larval alewives as well as the early life history preferences of other target species.

BIOGRAPHICAL SKETCH

Claire Stouthamer Ingel was born on May 23, 1987 in Fontana, California. She was raised in The Netherlands and returned to Southern California with her family in 2001. In 2005, she graduated from Redlands High School and began her study at the University of California, Davis. Spurred by the water disputes in California, she developed a strong interest for aquatic sciences and enthusiasm for conservation in human-dominated ecosystems. She received her Bachelors of Science in Biological Sciences with an emphasis in evolution and ecology in June 2009 and started working with Dr. Mark Bain in the Cornell University Department of Natural Resources in August of the same year. She continued working with Dr. Clifford Kraft in February, 2012.

To Dr. Mark Bain, for this opportunity, for his constant encouragement,

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INTRODUCTION

Subtidal and intertidal shallow water habitats have vital ecological roles in the Hudson River estuary (Strayer and Findlay 2010). Aquatic vegetation occurs only in the shallow portions of estuaries and provides habitat for production of forage species as well as spawning and nursery habitat (Miller et al 2006). As an estuary and a tidal river, the Hudson River functions as a nursery environment for the growth and development of early life stages of a variety of anadromous fishes (Blumberg and Hellweger 2006). Yet over the course of the 1900's, the morphology and hydrology of the Hudson River have been modified by dredging, filling and shoreline hardening (Miller et al 2006). Shoreline wetlands have also been altered by the construction of railroads along the river and dams in the upper drainage (Squires 1992; Schmidt and Cooper 1996). Throughout the river modification process, approximately 1740 ha (57%) of historic shallow water and intertidal habitats in the upper Hudson River have disappeared. Furthermore, the diurnal tidal amplitude of the Hudson River has increased in magnitude, causing higher water velocities during tidal exchange (Daniel Miller, personal communication). The loss of shallow-water habitat likely has had large effects on fish populations, but these effects have not yet been identified (Waldman et al 2006).

American shad (*Alosa sapidissima*), alewife (*A. pseudoharengus),* and blueback herring *A. aestivalis*) populations were dominant Hudson River fishes in the past and supported valued sport and commercial fisheries; however, in recent decades a marked decline in their abundance has been observed (Schmidt et al 1988; Limburg et al. 2006). At the same time, age, weight at first spawning, and number of repeat spawners have decreased for many Atlantic populations of these species, which has been attributed to the cumulative effect of fishery exploitation (Jessop 2003; Schmidt et al 2003). While alewife and blueback herring are currently managed together

as “river herring”, their spawning and life histories often vary by river system. When co-occurring, alewives tend to spawn in lentic sites and blueback herring spawn in lotic sites (Loesch 1987). In the Saint John River in New Brunswick, the spawning migration for both species begins in late April and lasts through early July (Jessop 2003). Alewives enter the river first, followed by blueback herring 2-3 weeks later (Jessop 2003). In the Hudson River, alewife juveniles typically have been reported to appear in near-shore waters from late June to mid-July while blueback herring recruitment to the juvenile stage begins at the beginning of July (Schmidt et al. 1988). Due to their differences in biology, a single management plan will affect each species differently and exploitation within a river system may be biased towards one species (Schmidt et al 2003).

Alosine fishes, members of the Clupeid subfamily alosinae, have planktonic larval phases that are vulnerable to passive transport dispersal (Schmidt et al 1988). Nevertheless, Limburg (1996) found greatest concentrations of American shad post-yolk sac larvae in or near aquatic vegetation and quiet waters. The Hudson River Habitat Restoration (HRHR) Project is a project proposed by the U.S. Army Corps of Engineers and New York District, in cooperation with the New York State Department of Environmental Conservation, New York State Department of State, Office of Parks, Recreation, and Historic Preservation, and The Nature Conservancy to restore intertidal freshwater wetlands within the Hudson River Estuary as part of a comprehensive restoration program (Yozzo et al. 2005). The HRHR project focuses on reclaiming formerly filled littoral nursery habitat to return aquatic ecosystem function and provide habitat for aquatic organisms, including alosine spawning and nursery habitat. Restoration of shallow water habitat may increase alewife reproductive potential; however, little previous research has evaluated the importance of these shallow nursery areas for alewife

development, growth, and feeding. This study examines the habitat dynamics of larval alewife in a reference shallow water reserve on the mainstem of the Hudson River Estuary with the goal of providing information relevant to habitat rehabilitation.

The study area is located within the Tivoli Bays reserve, one of the remaining shallow water zones along the upper Hudson River. As part of the Hudson River National Estuarine Research Reserve, Tivoli Bays are an important refuge for Hudson River resident marsh flora and fauna as well as a spawning and nursery habitat for several anadromous and resident freshwater fish species (Yozzo et al 2005). Backwaters and secondary channels flank the bays and encompass diverse habitats within a 2-km reach. These areas contain a range of shallow water conditions, substrate size, and water velocities. In the Tivoli Bays vegetation establishes in shallow, low velocity patches at variable times in the spring and is predominantly characterized by *Nuphar lutea*, *Vallisneria americana* and *Trapa natans*. Furthermore, the location of this potential nursery habitat relative to Magdalen and Cruger Islands - in combination with the diurnal tidal change of >1 m - results in the shallow water habitats being subjected to different velocities depending on the tidal stage.

This study 1) examined the intra-site influences of tide and structural habitat characteristics on the distribution of larval alewives, 2) examined the variability in habitat use and feeding over larval alewife ontogeny, and 3) characterized alewife habitat partitioning within the context of the rest of the shallow water fish community. Other studies examining larval fish distribution in shallow water areas have identified differences in habitat suitability among fishes (Scheidegger and Bain 1995; Childs et al 1998; Garner 1999; Arlinghaus et al 2002; Gadomski and Wagner 2009). These studies found differences in physical habitat parameters that were important for larval fish occupancy, suggesting that physical habitat constraints differ depending

on study system and fish species. In addition, differences in habitat use and feeding were found that indicated resource partitioning and overlap among and between species (Childs et al. 1998, Hobbs et al. 2006). This study was designed to explore the extent to which alewives in the Hudson River exhibited habitat associations such as those observed in previous investigations of larval fish in large river systems.

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CHAPTER 1

LARVAL ALEWIFE ASSOCIATION WITH MICROHABITAT GRADIENTS

Abstract

The continued decline of anadromous Atlantic river herring stock is of increasing concern and threatens a fishery closure throughout many Atlantic state fisheries. This study examined habitat use by the larvae of one river herring species, alewife (*Alosa pseudoharengus*) in a shallow nursery habitat of the upper Hudson River, New York. Larvae were collected by random point abundance sampling using a throw trap within three shallow water sites in the Tivoli Bays Estuarine Research Reserve. A logistic mixed effects model was developed to identify the habitat gradients favored by larval alewives. Habitat variables used in the model included water depth, water velocity, and vegetation cover as well as river water level and tidal change in water level. Alewives were more frequently present in lower velocity and deeper water while avoiding aquatic vegetation. Furthermore, larvae were caught more frequently during ebb tide and at low river water levels. These results suggest that considerable local variation occurs within nursery habitat and that this variability affects habitat suitability. Active orientations to structural habitat components as well as tidal transport mechanisms are suspected to influence intra-site alewife distribution. Restoration plans targeting larval alewife should take into account this intra-habitat variation.

Introduction

The anadromous and commercially harvested alewife (*Alosa pseudoharengus*) is recognized as an overexploited species across Atlantic fisheries (Limburg et al. 2006; ASMFC 2012. This decline has been primarily attributed to overexploitation from commercial fishing, although habitat loss has been cited as a factor hindering population recovery (ASMFC 1999). Compliant to the Atlantic States Marine Fisheries Commission amendment to regulate alewife and blueback herring (*A. aestivalis)* fisheries, the New York State Department of Environmental Conservation proposed to maintain a sustainable alewife and blueback herring fishery (Hattala et al 2011). The fishery will be restricted in the Hudson River and closed elsewhere in the state to prevent further population collapses (Hattala et al 2011).

The Hudson River is an important source for alewife spawning and early life history development. Through the 1970s, alewife, blueback herring, and American shad (*A. sapidissima*), were dominant in the Hudson River fish community (Schmidt et al. 1988); however, all three species are currently in decline (ASMFC 2011). Moreover, approximately 1740 ha (57%) of historic shallow water and intertidal habitats in the upper Hudson River have been lost due to dredging, filling, and shoreline hardening since the early 1900s (Miller et al. 2006). Most alewives spawn in the upper Hudson River estuary, upriver from the salt front (Schmidt et al. 1988). River margins and river tributaries have been identified as key spawning habitats. Juvenile alewives typically appear in near-shore waters from late June to mid-July and spend substantial periods of their early life history in the upper estuary (Schmidt et al. 1988). Consequently, the recovery potential of these alosine stocks through the rehabilitation of nursery areas is of particular interest (Miller et al 2006). The loss of shallow nursery habitat has likely

affected these fish populations, but specific effects have not been fully characterized (Waldman et al 2006).

All riverine fish exhibit specific life history strategies based on their relative dependence on flowing water habitats. Some species are specialized and adapted for passive transport downstream while others require flowing water for a portion of their life history and exhibit active lateral movements into new habitats (Csoboth and Garvey 2008). Conventionally, larvae were perceived to be weak swimmers, moving through high-drag environments in which swimming activity is energetically expensive (Hubbs and Blaxter 1986; Muller et al 2000). While the use of vertical migration is well recognized to alter dispersal trajectories, any active dispersal efforts were thought to have little influence (Norcross and Shaw 1984). Subsequently, recent studies have found in both marine and freshwater species that swimming speed increases with size and larvae can swim faster than ambient currents, thus having the potential for active dispersal (Fuiman et al. 1999; Garner 1999; Fisher et al 2000; Fisher and Bellwood 2002; Wolter and Arlinghaus 2003; Fisher et al. 2005; Henderson and Johnson 2010).

Alewife planktonic larval phases are vulnerable to passive transport dispersal (Schmidt et al 1988), but have also been observed to stratify within littoral habitats during early life. In Lake Ontario, early post-hatch larvae were most abundant in shallow areas less than 3m in depth, with larger larvae progressively occupying deeper habitat (Dunstall 1984). Greater densities of larval alewife were found in canals, oxbows, and creeks than in the main channel of the Roanoke River (Walsh et al 2005). In the Hudson River, Schmidt et al. (1988) found that juvenile near-shore catches remained large until the beginning of July with a successive increase in offshore trawl catches, signifying extended early life development in shallows. These littoral habitats could

provide an environment in which alewife larvae are able to utilize active transport and intra-site habitat variation.

Large-scale spatial and temporal fluctuations have been documented for alosine species in the Hudson River estuary and throughout the coastal tributaries, but early life small-scale spatial variability has not been closely examined. The goal of this study was to identify micro-scale habitat associations of larval alewife within their littoral environments for the purpose of informing nursery habitat restoration and examining larval utilization of active and passive transport mechanisms. Previously observed non-significant differences in larval alewife habitat association may be linked to high intra-site variability (Sismour 1994). Past studies examining other early life riverine fish species have been able to determine relative importance of microhabitat conditions through intense sampling within a small reach or patch (Scheidegger and Bain 1995; Childs et al 1998; Garner 1999; Arlinghaus et al 2002; Gadomski and Wagner 2009). In this study, a shallow water reach in the upper Hudson River was intensely sampled to determine intra-site variability in alewife distribution.

Site Description

The Tivoli Bays research reserve is located at river km 159 along the east bank of the Hudson River in Dutchess County, New York. As part of the Hudson River National Estuarine Research Reserve, Tivoli Bays are an important refuge for Hudson River resident marsh flora and fauna. (Yozzo et al 2005). Tivoli North Bay receives freshwater inputs from both the Hudson River and Stony Creek, which drains into the northern portion of the marsh. The bay is separated from the main channel by the Metro-North railroad and receives tidal water exchange with a diurnal tidal change of >1 m through bridges within the railroad bed (Yozzo et al. 2005).

This region of the estuary is upriver from the salt front and contains only freshwater habitat. Much of the areas outside of the bays are secondary channels and backwaters that are not exposed to high water velocities. Three sites in close proximity to one another were chosen to ensure sampling the range of shallow water habitat characteristics of the area: 1) Magdalen Island, 2) Railroad, and 3) Cruger Island (Figure 1.1).

Site 1, the Magdalen Island sampling site is located directly offshore of the eastern side of Magdalen island in a short secondary channel. This sampling region contains sloping shores and heterogeneous habitat with pockets of eddies interspersed with areas of higher velocities during tidal exchange. Spatterdock (*Nuphar lutea*) stands are present at this location in the early spring and water celery (*Vallisneria americana*) becomes prevalent in the late spring. Site 2, the Railroad site is located across from Magdalen Island and lies offshore of the Metro-North railroad enforcement. The banks are riprap-enforced, steep, and homogeneous; *V. americana* beds are located directly offshore. Site 3, the Cruger Island site is located directly south of Cruger Island and is categorized as a sheltered wetland (Findlay et al. 2002). This wetland is characterized by very low water velocities and contains dense stands of water chestnut (*Trapa natans*) during late spring and summer. The outer bay is more exposed, exchanging water directly with the river channel. *N. lutea* stands dominate the outer bay.

Methods

To assess habitat use of larval alewife, samples were collected across accessible shallow water locations at each of the three sites from May 9 to July 1, 2011 using stratified-random point abundance sampling executed during the daytime tidal cycle (Copp and Penáz 1988; Copp 1990). Fish samples were collected using a 1-m^2 W-fold throw trap and removed with a 1-m^2

500 micron bar mesh seine (Rozas and Odum 1987; Controneo and Yozzo 2010). Each trap was seined multiple times until no fish were caught for two consecutive seine passes (Figure 1.2). Random sample points were generated using Hawth's Tools in ArcMap and were located in the field using a GPS unit (Beyer 2004). Samples were taken as close to the true predetermined location as possible or excluded if inaccessible due to prevailing water depths associated with river water level.

Microhabitat conditions were recorded immediately after trap deployment to avoid changes in depth and velocity with the tidal cycle (Table 1.1). Measurements recorded at each sampling point included: GPS coordinates, day, time, depth measured to the nearest 0.1 m, current velocity at 0.6 depth to the nearest 0.01 m/s with a digital flow meter, estimated percent density of cover, estimated vegetation density by species (Bain and Boltz 1992), and substrate (Bain et al. 1985). Water level, temperature, and dissolved oxygen (DO) measurements were obtained from the Hudson River Environmental Conditions Observing System (HRECOS) gauge data for Tivoli North Bay and Tivoli South Bay (NOAA 2004).

All species of fish larvae were preserved in 10% buffered formalin and other obviously post-larval fishes were identified, measured, and released. Collected fish were fixed in formalin for a minimum of 2 weeks, leached in water, and transferred to 70% ethanol. Larvae were counted and larval Clupeidae were separated from other families (Auer 1982). Larval alewives were distinguished from blueback herring and American shad by their size, ontogenetic characters, and post-myomere count between dorsal and anal fins (Jones et al 1978; Walsh et al 2005) and classified as yolk sac larva, post-yolk sac larvae, or juvenile. Juveniles were identified by the loss of the median finfold and the presence of all spines and rays in each fin. Only yolk-sac and post-yolk sac larvae were included in this study; all juvenile fish were excluded after

classification.

Tidal and seasonal variables (tidal flux, maximum water velocity, and degree-day) were calculated for each trap sample using water level measurements from the HRECOS gauges and velocity interpolation. Tidal change in water level was calculated as the change in gauged water level over 15 minute intervals (m/hr). Empirical water velocities measured at maximum tidal change in water level were separated by ebb and flow tide. The kriging function in ArcMap was used to interpolate maximum velocity surfaces for the complete sampling area using the ebb and flow datasets (ESRI 2011). The interpolated values of both the ebb and flow surfaces were assigned to each empirical sampling point. The maximum velocity at each empirical sampling point was defined as the larger of the two interpolated velocities. Degree-days were calculated to serve as a measure of longitudinal changes in larval prevalence (Table 1.1). A metric of the optimal hatching temperature for alewife larvae (T_{base}) was defined as 16°C, as used by Edsall (1970).

Habitat differences between the three sampling locations were detected by analysis of variance (ANOVA). If differences were detected between sampling locations, the Tukey-Cramer HSD test was used to determine differences among the mean habitats variables of individual locations.

To determine alewife use of variable microhabitat characteristics, alewife prevalence was modeled using logistic regression (Figure 1.3). Prevalence was coded as 1 if fish were present and 0 if not present in a sample. Larval presence was correlated to habitat variables using a mixed-effects model specified by Eq. 1.1 and following the notation of Zuur et al (2009):

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + \beta_1 X_{1ij} + \cdots + \beta_n X_{nij} + a_i + \varepsilon_{ij}$$

$$a_i \sim N(0, \sigma_a^2)$$

$$\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2) \quad (1.1)$$

where p_{ij} is the probability that sample j in site i contains alewives, X_{1ij} through X_{nij} are the n microhabitat fixed effects, a_i is the random site effect, and ε_{ij} is the residual error. The Akaike Information Criterion (AIC) was used to examine the significance of each microhabitat fixed effect and interactions between fixed effects (Akaike 1974). In order to account for the potential influence of autocorrelation within each of the three sampling sites, two models were constructed and compared to account for the variance associated with site, collection date, and season: 1) a mixed effects model including fixed effects and a random site effect, and 2) a mixed effects model including fixed effects, a random site effect, and an interaction between degree-day and site. All fixed effects were examined for collinearity with other habitat variables before being added to the model. Models were constructed and analyzed using the "lme4" package for generalized linear mixed-effects models (R Development Core Team; Bates et al. 2011).

Results

Several key differences in habitat conditions were observed between sampling sites (Table 1.2). Cruger Island had significantly lower maximum velocities than the Railroad and Magdalen Island sites ($p<0.0001$, F-value= 54.163) and point velocities were also lower ($p<0001$, F-value=15.445). A difference in sampled depth ranges was observed between sites ($p=0.033$, F-value=3.447) due to the steep banks generating deeper water habitat at the Railroad site, especially during high tidal levels. The Cruger Island site contained more vegetation than the other two sites ($p<0.0001$, F-value=13.704), consisting predominantly of *T. natans* that

formed dense patches by mid-June. The three main vegetation types found were *V. americana*, *T. natans*, and *N. lutea*. Cruger Island samples were taken further from shore than at the other two locations ($p<0.0001$, F-value=13.793). No significant differences in dissolved oxygen and temperature were found between the three sites. Water temperature peaked at 27.3°C early in the season, but remained between 26°C and 22°C for the rest of the sampling period. Mean dissolved oxygen levels were around 6.7 mg/l and only occasionally dropped below 4 mg/l during low tides. Turbidity levels remained between -20 and 30 NTU for the majority of the sampling period at all sites, but spiked to over 150 NTU on one sampling day. This turbidity spike increased the average turbidity for the Cruger Island site, but this average value does not reflect the seasonal trend.

A total of 75 out of 192 traps sampled contained alewife larvae, which ranged from 3.0-20.9 mm in size. Alewife larvae first appeared in traps on May 31, 2011, so all trap samples collected prior to this date were excluded from analysis. Over the sampling season, 4072 larval and juvenile fish of various species were collected for analysis and 1304 of these individuals were identified as alewife larvae. More traps contained alewives at Magdalene Island (42 out of 72 traps) than at Cruger Island (17 out of 60 traps) or Railroad adjacent (17 out of 63 traps) (Figure 1.4). The number of alewives collected ranged from 0-360 larvae per trap, with a mean density of 7 fish per trap and a median density of 0 fish per trap (Figure 1.3).

The AIC scores from each of the two models were used to examine the level of support for each of the two binomial mixed-effects models tested. The mixed effects model without degree-day interaction received the most support from the data (Table 1.3). Alewives were found more frequently in deeper water, at lower water velocities, and outside of aquatic vegetation

(Figure 1.5). The probability of catch increased during ebb tide and lower water levels. The empirical model is specified by Eq. 1.2:

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + \beta_1 \mathrm{Veg}_{ij} + \beta_2 \mathrm{Level}_{ij} + \beta_3 \mathrm{Depth}_{ij} + \beta_4 \mathrm{Vel}_{ij} + \beta_5 \mathrm{Tidal}\Delta_{ij} + a_i + \varepsilon_{ij}$$

$$a_i \sim N(0, \sigma_a^2)$$

$$\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2) \qquad (1.2)$$

where p_{ij} is the probability that sample j in site i contains alewives, Veg_{ij} is the vegetation density, Level_{ij} is the water level, Depth_{ij} is the water depth, Vel_{ij} is the water velocity, and $\mathrm{Tidal}\Delta_{ij}$ is the tidal change in water level (see Table 1.1 for descriptions). The random site effect a_i is assumed to be normally distributed with a variance of 0.47. Parameter estimates are listed in Table 1.4, along with the order of coefficient selection by stepwise regression.

Temperature, dissolved oxygen, and turbidity were similar at all three sites and were not correlated to alewife presence. Furthermore, substrate size, distance from shore, and maximum water velocity did not show correlation to alewife distribution. No interactions between fixed effects were found to improve the model.

Discussion

Several intra-habitat differences in alewife microhabitat use were identified. Alewives were found more frequently in low velocity habitats, deeper water, and away from aquatic vegetation. Furthermore, larvae were captured more frequently during ebb tide and during periods of low tide. Consistent with previous studies (e.g. Floyd et al. 1984; Scheidegger and Bain 1995; Garner 1996; Childs et al. 1998) this study shows that micro-scale habitat conditions

are important for structuring larval fish communities. Alewife larvae respond to microscale structural habitat gradients, indicating that there may be variation in suitable near-shore nursery habitat. Furthermore, due to their preference associated with low-velocity habitat, larval alewife may utilize active orientation and swimming within these near-shore low-flow environments.

At all sites, alewives were most commonly found at slower water velocities and deeper sampling locations. Larval alewives were consistently found in water velocities up to 12 cm/sec, but not in faster currents. Sample depths ranged from 0.13-1.23 meters, but very few larvae were found at sampling locations shallower than 0.5 m. These findings are consistent with past studies of alewife larvae and other fishes. Schmidt (1986) found that river herring occupy deeper channels rather than shallow, intertidal backwaters within Tivoli Bays. Pelagic fishes are common near shore where waves can suspend food items, but are found in the lower portion of the water column where water current motion is reduced by both depth and bottom effects (Webb et al 2010). Even within velocity limits, larger fish have been found to occupy lower velocity areas (Childs et al 1998). Previous field observations support low-velocity preference and validate the importance of low-velocity areas as nursery habitat. For example, age-0 fishes prefer low water velocity conditions near the shoreline (Floyd et al. 1984). Low velocity habitats such as backwaters, tributaries, and near-shore areas support high densities of larval fish (Odom 1987; Scott and Nielsen 1989). Freeman et al. (2001) found that in regulated rivers, the abundances of age-0 fishes were frequently correlated with availability and persistence of shallow-slow habitat during the spring and summer. The strong correlation between alewife presence and point velocities rather than maximum velocities indicates that larval distribution is based on instantaneous velocity changes, not tidal fluctuations. Larvae are not solely distributed in pockets of constant low-velocity habitat, but also occur in areas subjected to greater water

velocities over the tidal period. Larvae would need to disperse into low-velocity areas after the period of high-velocity tidal flux to use these newly established low-velocity environments.

Aquatic vegetation only grows in the shallow portions of the Hudson River and has been thought to provide spawning and nursery habitat for anadromous and resident fishes (Miller et al 2006); however, in the case of alewives, larval catch was inversely related to vegetation density. In fact, larvae were most frequently found in areas with less than 10 percent vegetation density and were never found in areas where vegetation density exceeded 30 percent. Other Hudson River studies have found similar results: Anderson and Schmidt (1989) found that alewife larvae were a dominant fish species prior to the development of dense water-chestnut cover, but no longer inhabited these areas after the establishment of this invasive plant, while larval minnows and killifish persisted in the dense beds. Schmidt and Kiviat (1988) caught small numbers of larval alewife in water-chestnut and water celery beds compared to minnows and killifish larvae. Considering that passive dispersal would promote larval fish concentration in low-velocity vegetation beds, alewives likely utilize a form of active dispersal to avoid vegetation beds.

Larval alewives may encounter both positive and negative influences associated with submerged aquatic vegetation that were not measured in this study. Anoxia sensitivity may affect alewife vegetation avoidance. Water chestnut invaded the Hudson River in the late 1800's and has established prolific seed banks throughout the estuary. Alewife larvae have been found to require DO levels of at least 5.0 mg/L (Jones 1988). When water chestnut patches become dense, DO levels have been measured to decrease to 3 mg/L, which is out of the tolerable range for alewives (Caraco and Cole 2002). While alewives were not often found directly in aquatic vegetation, each sampling location contained patches of aquatic vegetation nearby. Larval alewife may benefit from the close presence of aquatic vegetation without associating with its

physical structure. For instance, emergent macrophytes in marshes reduce wave action and turbulence. In addition, patches of differing vegetative cover are considered "hot spots" of primary production and nutrient cycling, which may benefit larval growth and survival (Madsen et al. 2001; Webb et al 2010). While results from this study suggest that alewife larvae avoid vegetation, the broader influence and mechanisms of vegetation have not yet been quantified.

Temperature, turbidity, and DO have been found to be important in structuring the early life history of alewives. In Muskegon Lake, higher temperatures and turbidity along with greater primary production and zooplankton abundance contributed to earlier alewife hatching dates and a better growth environment, leading to slightly higher growth rates and mean individual condition (Höök et al 2007). The Rappahannock River alewife population showed positive associations with egg occurrence in relation to temperature and dissolved oxygen (O'Connell and Angermeier 1997). Conversely, in this Hudson River study, the gauged temperature, DO, and turbidity were apparently not different enough to influence alewife prevalence in any of the three habitats. Finer measurements may have increased these associations; however, the Hudson River is known to be a well-mixed system (Cole et al 1992; reviewed in Findlay et al 2006) and differences may not have been detectable on an intra-site scale.

Channelization has increased the diurnal tidal amplitude of the Hudson River by increasing its magnitude, which produces higher water velocities during tidal exchange (Daniel Miller, personal communication). Alewife prevalence was positively correlated with lower river water levels, with alewife catch increasing at low tide. Increased probabilities of catch and concentrating effects have been associated with lower tides and are frequently observed in tidal embayments (Rozas and Minello 1997). The tidal amplitude in the Tivoli Bays region often fluctuates by more than one meter per period, which results in a significant reduction in water

volume over the three locations sampled. However, other mechanisms could be driving the positive correlation between alewife and low water levels, such as larval avoidance of the offshore channel to avoid downriver transport. Furthermore, alewife catch increased during ebb tide. Similarly, Limburg and Strayer (1988) found an increase in catch per unit effort of larval river herring being transported out of Tivoli North Bay during ebb tides; however, Bohne and Schmidt (1989) found an increase of alewife larvae drifting into Tivoli Bays during flow tidal flux. These contrasting catch abundance results in different studies may suggest a greater influence of river hydrodynamics rather than larval behavior concerning the tidal influence of alewife distribution.

Further study is necessary to determine the dominant mechanism of larval alewife dispersal in the Hudson River. Pelagic larvae are spawned in upstream areas, then disperse and retained in slow-flowing nursery habitats (Wolter and Sukhodlov 2008). Generally, freshwater fish develop the ability to swim freely at lengths ranging from 6-15 mm and have mean burst speeds ranging from 0.06-0.19 m/s, which is within the range of water velocities measured in this study (Wolter and Arlinghaus 2003). The frequency of larvae associating with physical habitat parameters (water velocity, water depth, and vegetation) indicates possible active dispersal and orientation in these nursery habitats (Scheidegger and Bain 1995), but the dispersal mechanism relating to the tidal parameters (river water depth and tidal flux) remains ambiguous. Addressing the tidal influence on the distribution of larval alewives can provide a better indication of larval retention in the nursery areas as well as larval flux between the river channel and nursery zones.

Considering these study results, several specific components should be considered for shallow water habitat restoration. Although larval fish were more frequently found in areas of low velocity, these areas also aid the establishment of dense vegetation patches (Madsen et al

2001). Careful consideration must be given to creating shallow water areas that limit the establishment of thick vegetation while maintaining favorable depth and velocity conditions. While this study determines the structural trends associated with alewife early life habitat improvement, it fails to quantify larval densities that these habitats contribute to the river population. Nursery habitats produce more adult recruits per unit area than other juvenile habitats used by a species (Beck et al 2001). It is essential for further studies to investigate the relative contribution of larval and juvenile alewives from shallow waters in contrast to the main channel to understand the potential impact of off-channel shallow water habitat restoration on alewife production, growth, and survival.

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Figure 1.1. Site map

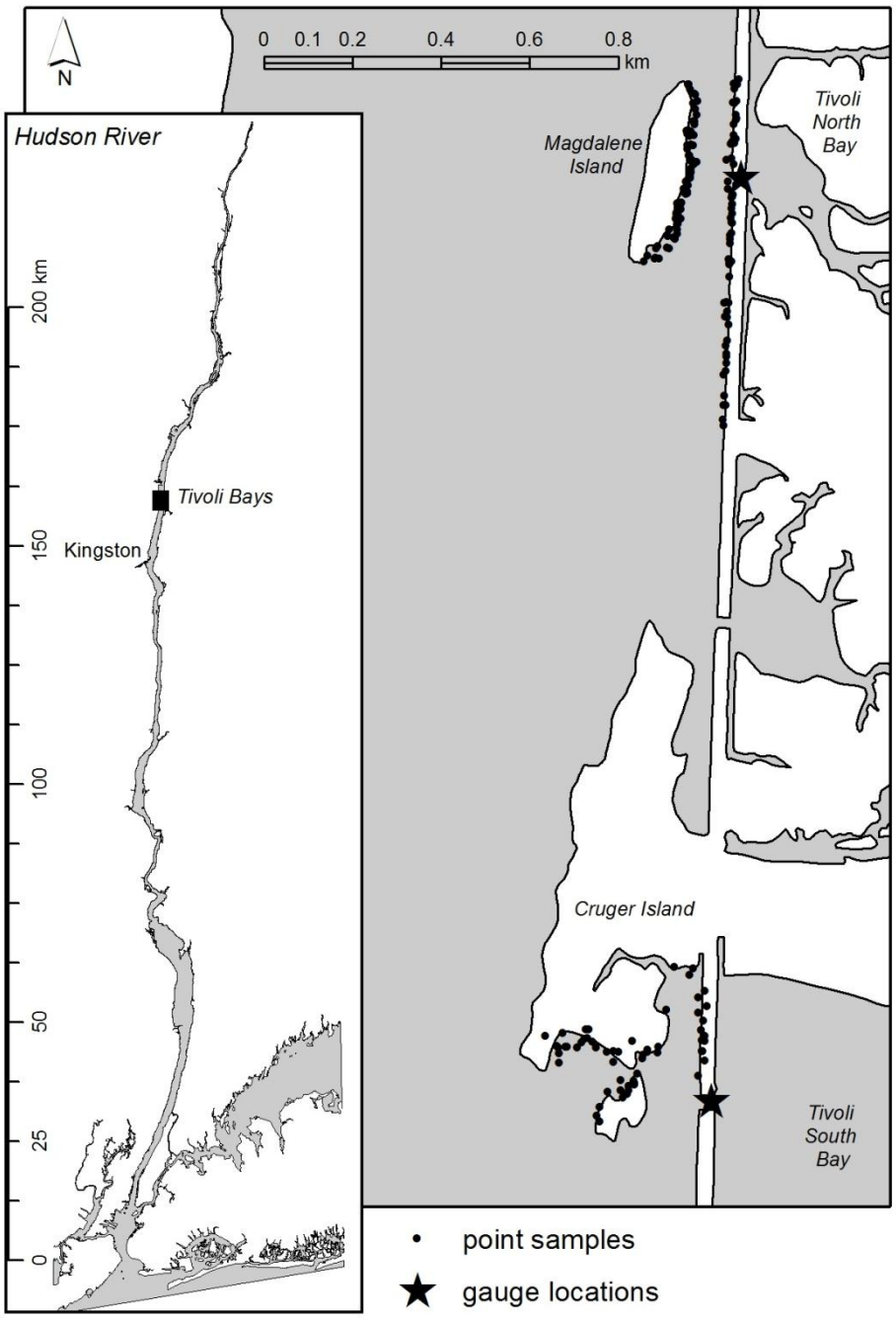

Figure 1.2. Throw trap and bar seine

Figure 1.3. Box plot of alewife catch per unit effort values by site and sampling interval. Plot indicates sample distribution, interquartile range (IQR), median, and outliers (larger than 1.5 * IQR). The y-axis is on a log10 scale.

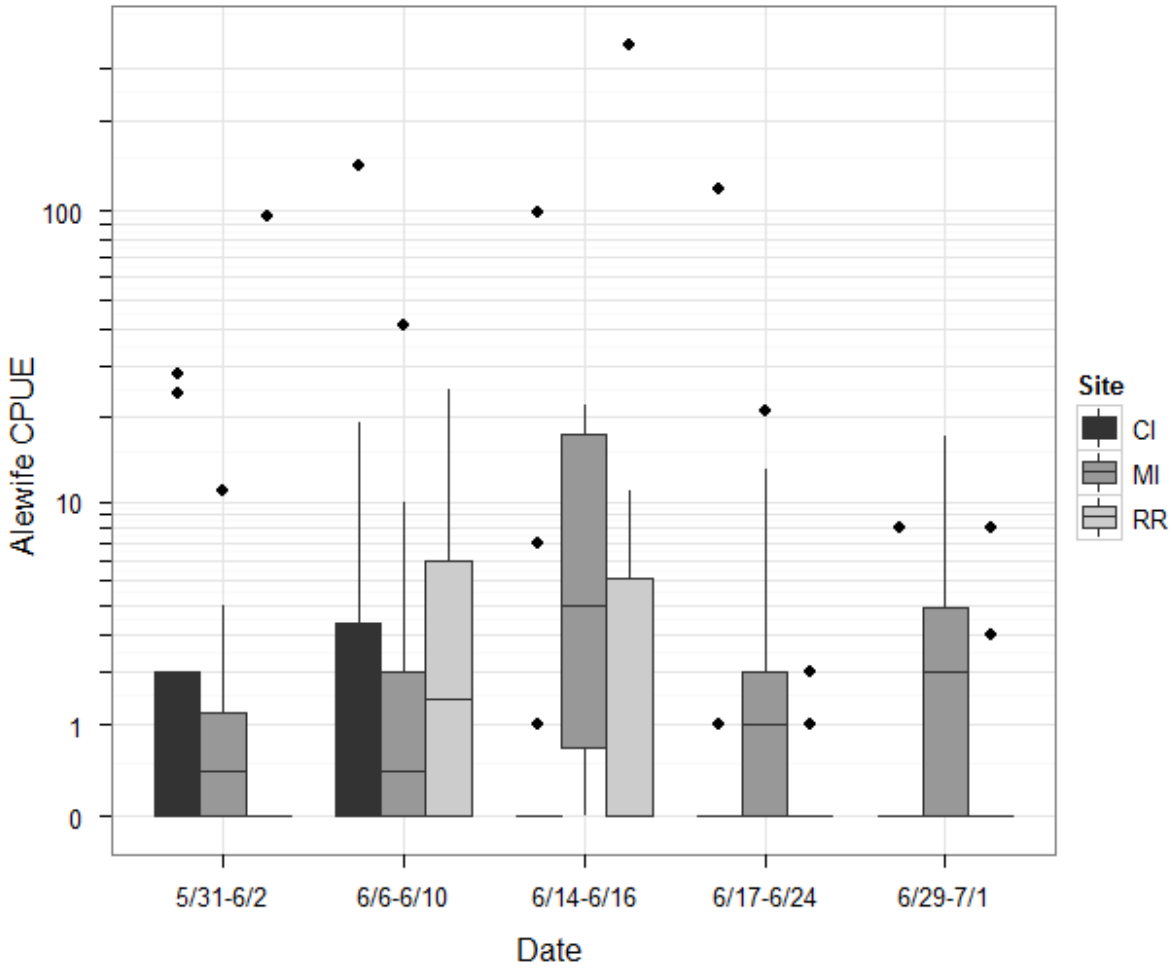

Figure 1.4. Bar plot of percentage of traps containing alewife larvae by sampling interval and site. Values listed above bars indicate the number of samples represented.

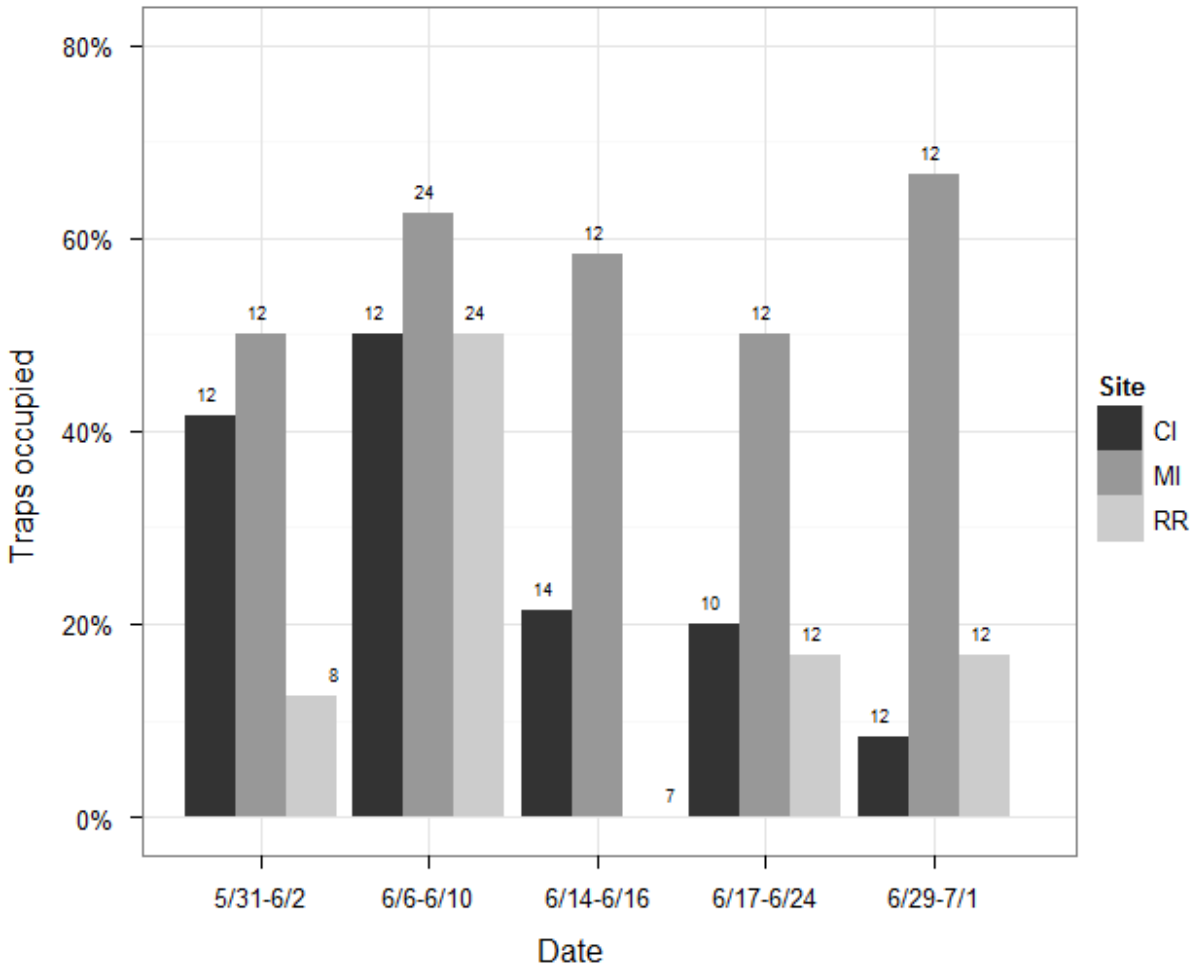

Figure 1.5. Trends of significant habitat variables. The solid line indicates the model fit for each variable while keeping all other variables constant at their mean values. The dotted lined indicate the 95% confidence interval associated with each variable fit. Darkness of filled circles indicates a greater number of samples.

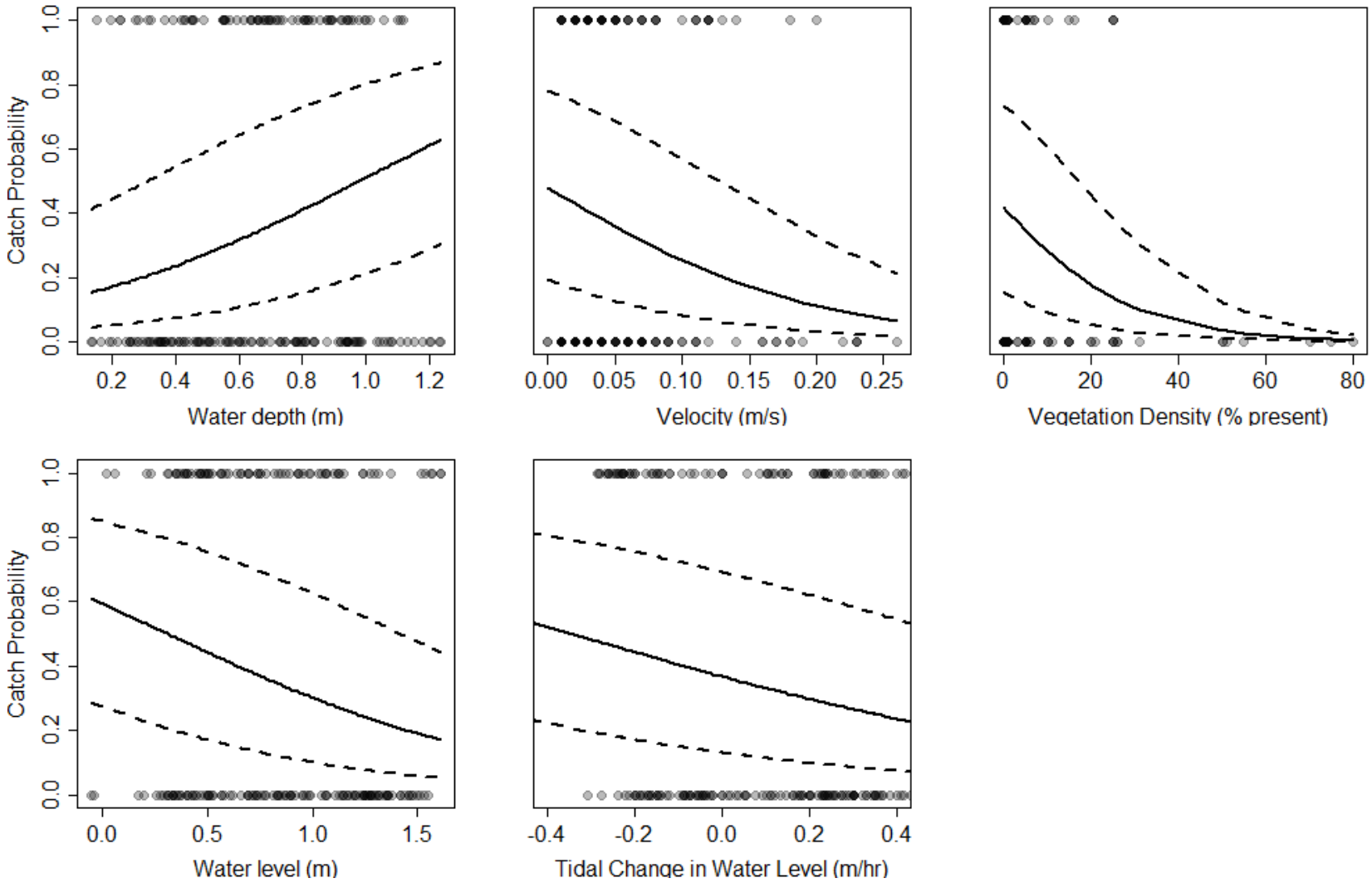

Table 1.1. Description of habitat variables

Variable	Description
Water velocity	Instantaneous water velocity in meters per second measured at each sample with a Marsh-McBirney flow meter and averaged over 30 seconds.
Water depth	Mean water depth in meters at each sampling point
Distance from shore	Length in meters from the sample to the wetted shoreline
Vegetation density	Visual percent estimate of all aquatic vegetation within the 1 m^2 substrate area of the throw trap
Substrate	Twenty substrate observations were taken at every sample and coded as a mean substrate value. Mean substrate was classified according to Bain et al 1985.
Dissolved oxygen	Amount of dissolved oxygen in the water, recorded every 15 minutes as mg/L (HRECOS gauge measurements)
Temperature	Water temperature, recorded every 15 minutes as degrees Celsius (HRECOS gauge measurements)
Turbidity	Amount of suspended particles in the water column recorded every 15 minutes as Nephelometric Turbidity Units (NTU) (HRECOS gauge measurements)
Degree-day	Measure of heat accumulation or seasonality Degree days $= \sum T_{avg} - T_{base}$. T_{avg} is the daily average water temperature (HRECOS gauge measurements). T_{base} is defined as 16°C, the optimal hatching temperature for alewife larvae (Edsall 1970)
Water level	River water level measured at a fixed point at 15 minute intervals (HRECOS gauge measurements)
Maximum water velocity	The maximum water velocity at each sample, interpolated from velocity measurements during maximum tidal flux
Tidal change in water level	The change in water level over 15 minute intervals converted to meters per hour (HRECOS gauge measurements).

Table 1.2. Mean and standard error (SE) values for the habitat characteristics and mean habitat characteristics for each sampling site.

Fixed effects	Cruger Island	Railroad	Magdalen Island	Total	
	Mean	Mean	Mean	Mean	(SE)
Water velocity (m/s)	0.03	0.07	0.07	0.06	(0.004)
Water depth (m)	0.62	0.73	0.62	0.66	(0.02)
Distance from shore (m)	9.5	3.7	6.3	6.4	(0.47)
Vegetation density (%)	12	3	2	5	(0.9)
Dissolved oxygen (mg/L)	7.2	6.7	6.3	6.7	(0.1)
Temperature (°C)	23.1	23.4	23.2	23.2	(0.1)
Turbidity (NTU)	37.2	6.3	6.7	14.6	(2.3)
Degree-day	128.5	123.2	116.2	122.3	(4.2)
Water level (m)	0.8	0.9	0.8	0.8	(0.03)
Max water velocity (m/s)	0.04	0.09	0.11	0.08	(0.003)
Tidal change (m/hr)	0.05	0.04	0.09	0.06	(0.016)

Table 1.3. Comparisons of two logistic generalized linear mixed models. GLMM site: mixed effects model with site as a random effect, GLMM site*dd: mixed effects model with site as a random effect and degree-day as a longitudinal component. Fixed effects in each model include water velocity, water depth, vegetation density, water level, and tidal flux. The random effect in each model is site. GLMM site*dd additionally included the degree day fixed effect.

Model type	Residual deviance	AIC	ΔAIC
GLMM site	225.1	239.1	-
GLMM site*dd	228.1	244.1	5.0

Table 1.4. Parameter estimates for logistic mixed effects model with random site effect, added in order by stepwise regression. Veg_{ij} is the vegetation density, Level_{ij} is the water level, Depth_{ij} is the water depth, Vel_{ij} is the water velocity, and $\mathrm{Tidal}\Delta_{ij}$ is the tidal change in water level. Fixed effect significance: z< 0.01**, z< 0.05 *, z<0.1 ·

Intercept	$\mathrm{Tidal}\Delta_{ij}$	Veg_{ij}	Vel_{ij}	Depth_{ij}	Level_{ij}	AIC	ΔAIC
0.02	-1.58 *	-0.06 *	-9.94 **	2.02 **	-1.22 **	239.1	-
0.02	-1.24 ·	-0.05 *		1.82 **	-1.16**	244.2	5.1
-0.59	-1.86 *	-0.05 ·	-8.58 *	1.25 *		244.6	5.5
0.16	-1.83 *	-0.04 ·	-7.42 *			246.8	7.7
-0.29	-1.53 *	-0.04 ·				249.5	10.4
-0.44	-1.55 *					251.7	12.6
-0.52						254.9	15.8

CHAPTER 2

DISTRIBUTION, GROWTH, AND FEEDING DURING LARVAL ALEWIFE ONTOGENESIS

Abstract

The relative abundance of many fish species is established in the first weeks of life. During the larval stage, often called the 'critical period,' fishes typically experience mortality greater than 90%. Ontogenetic changes begin in the embryo and continue after hatching so that additional physiological and behavioral capabilities increase with age. This study examined the shift in habitat use and feeding of alewife (*Alosa pseudoharengus*) over the larval period. A linear model was developed to explore the relationship between fish size and a variety of habitat and biological community metrics, including available habitat, degree-days, larval density, and feeding incidence. Furthermore, larval diets were examined to identify feeding shifts over larval ontogeny. Finally, age and size of recently fed and empty gut fish were studied to detect any effects of long-term starvation upon condition. Distinct shifts in habitat association and diet were found in feeding larvae. Larger fish were found at locations with deeper water and higher water velocity. Alewives feed on microzooplankton when first feeding and shift to progressively larger prey organisms as they grow. No long-term differences in growth were found between recently fed and empty gut larvae. The observed shifts in microhabitat association and prey choice have implications for rehabilitating suitable nursery habitats. Rehabilitation should include microscale heterogeneity to accommodate the range of ontogenetic habitat associations of larval alewives.

Introduction

The larval period of fishes is a dynamic interval during which the majority of ontogeny takes place and biomass begins to increase (Fuiman 2002). Throughout much of this stage, swimming ability is not yet well-developed and larvae tend to be more susceptible to starvation and predation (Miller et al 1988). This increased susceptibility requires larvae to exhibit environmental requirements, behaviors, and habitat needs distinct from those of juvenile and adult fishes (Snyder 1990). Increases in size, structure, and physiological capabilities begin developing in the embryo and change rapidly as larvae attempt to survive (Fuiman 2002). Consequently, the larval period is characterized by high mortality and is considered a critical period in the population dynamics of many species (Hjort 1914; Marr 1956; May 1974).

Larval fish survival is dependent on prey availability and effective feeding. For example, a previous study showed that complete mortality of starved river herring occurred 8 days post-hatch (Sismour 1994). The critical period of first feeding (Hjort 1926) can have a profound effect on year-class size (May 1974), but is not the only period in larval development influencing survival. Fish larvae that lack adequate food have been found to grow more slowly and experience increased mortality from predators (Hunter 1981; Sinclair and Tremblay 1984; Rice et al. 1987; Hoey and McCormick 2004). Low prey abundance in nursery areas has been associated with poor condition factor, poor survival, and in some cases low growth (Crecco and Savoy 1985, 1987; Johnson and Dropkin 1995; Limburg 1996). Even short-term food deprivation can cause decreases in condition and increased mortality (Johnson and Dropkin 1995).

Although the early life phase of fishes is generally brief, the physiological and morphological changes that take place during this period effectively alter feeding, locomotion

and survival (Fuiman 2002). Critical swimming ability increases in a predictable manner in relation to developmental age and size (Fisher et al. 2000; Wolter and Arlinghaus 2003) and is species-specific as well as length-specific (Mann and Bass 1997; Fuiman et al. 1999; Garner 1999; Fisher et al. 2005). Furthermore, distinct phases within larval ontogenesis seem to influence positioning within the environment. Stress periods observed in some previous studies were correlated with a common point in larval ontogeny 5-10 days after first feeding, such as the migration to the hypolimnion, rather than an external, truncated environmental event (Rice 1987). Childs et al. (1998) found that diet evaluations of larval fishes supported differences observed in feeding location and also identified differences in diel feeding patterns between species size categories. Overall, microhabitat preferences by larval fish might influence growth and feeding.

Early life history and ontogenetic studies both in controlled laboratory environments (Edsall 1970; Kellogg 1982; Sismour 1994) and field studies (O'Connell and Angermeier 1997; Walsh et al. 2005; Höök et al 2007) have contributed valuable understanding to the early life history of alewives (*Alosa pseudoharengus*). However, it is not known how alewife growth and feeding success influence their habitat selection, or how alewife microhabitat use influences fish growth and feeding success. The ecological context of alewife larval ontogeny is important to consider when restoring spawning and nursery areas of this species. This study examines shifts in habitat use over alewife ontogenesis and differences in feeding and growth associated with microhabitat factors.

Methods

Larval alewives were collected from the near-shore zone directly adjacent to Tivoli Bays, NY. Habitat spanned calm backwaters, exposed enforced banks, and heterogeneous eddies. Sampling maps, habitat measurements, and larval alewife collections are described in Chapter 1 of this thesis. Fish were collected by stratified point-abundance sampling using a throw trap and bar seine, and habitat variables were recorded at each sampling point. Measured habitat characteristics were the same as those identified in Chapter 1 of this volume (for a complete list and descriptions, see Table 1.1). Most larvae were preserved in 10% buffered formalin, but subsamples of larvae were preserved in 95% ethanol for otolith aging.

Alewife larvae were separated from alewife juveniles and other fish larvae. All larvae in samples containing 25 or fewer formalin-fixed fish were rehydrated and measured; otherwise 25 larvae were selected randomly. Entire digestive tracts were removed and all undigested zooplankton were counted and identified using identification keys by Edmondson (1959), Pennak (1989), and Balcer (1984). Additional guidance in identifying zooplankton was provided by Pace et al (1998), which identified the common zooplankton of the sampling area. While phytoplankton was occasionally found in the digestive tract, only zooplankton densities were identified and quantified. Zooplankton was categorized as cladocerans, copepods, veligers, nauplii, or rotifers. Diet counts were converted to dry weights based on average Hudson River zooplankton weights provided by Pace et al. (1992): 1.21, 0.737, 0.363, and 0.0324 µg for individual copepods, cladocerans, nauplii, and rotifers respectively. Zebra mussel (*Dreissena polymorpha*) veliger dry weight was estimated from the regression in Mackie (1991):

$$\text{Total dry weight } (\mu g) = 0.051 \text{Length}^{2.996} \qquad (2.1)$$

The average veliger length observed in this study was 140µm, which was used for all veligers counted. Both mean number and mean biomass consumed was quantified for larval fish collected during the sampling period.

To determine ontogenetic microhabitat shifts and feeding success associated with larval size, a linear model was constructed using the measurements and digestive tract analysis from the formalin-fixed larval alewives to evaluate the influence of fish size, habitat characteristics, and feeding incidence upon the response variable, total length (TL):

$$\mathrm{TL} = \beta_0 + \beta_1 \mathrm{X}_1 + \beta_2 \mathrm{X}_2 + \cdots + \beta_n \mathrm{X}_n + \varepsilon$$
$$\varepsilon \sim N(0, \sigma_\varepsilon^2) \qquad (2.2)$$

where TL is the mean sample total length, X_1 is the feeding incidence effect, X_2 through X_n are the n microhabitat effects, and ε is the residual error. Mean sample total lengths were used to avoid pseudoreplication between fish from the same trap. Feeding incidence was calculated as the proportion of total larvae examined with one or more prey in the gut. The model was weighted by $(\sigma_{TL}^2 + 1)^{-1}$ to attribute a greater weight to samples with a lower size variance.

Gut contents were analyzed from the 95% ethanol-preserved fish to evaluate relationships between feeding status and growth rate. All prey items in the digestive tract of each fish were counted. Fish were defined as having "recently fed" if at least one prey item was found in their digestive tract; otherwise fish were defined as "empty." The subsamples of ethanol-preserved alewives were processed for otolith aging. Sagittal otoliths were extracted, dried, and mounted on microscope slides in clear adhesive. Each set of otoliths was photographed and daily growth

increments were counted to determine individual fish age. Otoliths were examined twice by the same individual, without knowledge of specimen identity. Increment counts were compared and otoliths were read a third time if ages differed by more than one day. Fish were excluded from analysis if the third reading differed by more than 1 day from either of the first two counts.

To examine the relationship between alewife size, growth, and feeding, a linear model was developed using the standard length (SL) of the ethanol-preserved alewife larvae as the response variable and with age and feeding status as the predictor variables:

$$\mathrm{SL} = \beta_0 + \beta_1 \mathrm{age} + \beta_2 \mathrm{feeding} + \varepsilon$$
$$\varepsilon \sim N(0, \sigma_\varepsilon^2) \qquad (2.3)$$

where SL is the individual fish standard length, age is the fish age in days, and feeding is the feeding status of the fish coded as 0 if the fish was defined as "empty" or 1 if the fish was defined as "recently fed", and ε is the residual error. The purpose of this regression was to determine if instantaneous feeding status was indicative of a long-term feeding trend and to associate feeding status with fish condition.

Results

A total of 626 formalin-preserved fish from 72 samples and 163 ethanol-preserved fish from 11 samples were measured and processed. Alewives ranged in size from 3.0-20.9 mm and recently fed fish were generally larger than fish with empty guts (mean TL 7.9 mm and 11.9 mm, respectively). The number of prey in the digestive tract ranged from 0-176 organisms. Prey included the adult cyclopoid copepods *Diacyclops thomasi* and *Halicyclops spp*, and the calanoid

copepod *Eurytemora affinis*. Cladocerans were mainly represented by *Bosmina freyii*, but also included other *Bosmina* and *Daphnia spp.* Veliger larvae were represented by *D. polymorpha*. No attempt was made to identify nauplii and rotifers to more finely resolved taxa.

Ontogenetic shifts were found for depth and velocity, feeding incidence, density, and degree-day (R^2: 0.70, R^2 adjusted: 0.66, $p < 0.0001$) (Table 2.1). Alewife larvae were larger later in the season and tended to congregate in larger groups. At high feeding incidence (FI=1 all fish feeding), larger fish were found at locations with greater water velocities and deeper depths. At low feeding incidence (FI=0, no fish feeding), the depth and velocity terms became zero and no longer established an association between habitat variables and fish size (Table 2.1). The interaction effect between water velocity and water depth indicates an inverse relationship between the two factors: larvae of the same size are likely to be found in deeper water at a lower velocity or in shallower water at a higher velocity (Figure 2.1).

Distinct shifts in prey consumption were detected in larvae at 8mm, 12mm, and 14mm in length (Figure 2.2 and 2.3). Small larvae less than 7mm in length were rarely found with prey items in their guts, but when prey items were found, rotifers were most commonly consumed. At 8mm, nauplii and adult copepods were consumed at the greatest frequency and copepods accounted for the largest gut biomass. At 12mm, copepods accounted for the largest biomass and number of items consumed, but zebra mussel veliger larvae, nauplii, and cladocerans were also important components in the diet. At 16 mm, cladocerans were consumed most frequently and accounted for the largest biomass of prey consumed, whereas zebra mussel veligers and nauplii accounted for less of the total biomass consumed.

Based on the subsample of fish preserved in 95% ethanol, small larvae less than 11mm in length were rarely found with food in their digestive tracts while larvae greater than 15mm in

length were generally successful feeders (Figure 2.4). Age was a suitable predictor of alewife size, but feeding status was not a suitable predictor of alewife size (Table 2.2). No size differences were found when comparing recently fed and fish with empty guts of the same age (Figure 2.4). Consequently, no relationship was observed between instantaneous feeding and condition.

Discussion

Shifts in habitat use by larval alewives corresponding to changes in size and feeding status indicate ontogenetic changes in habitat association. When recently fed, alewives appear to stratify by depth and velocity, with bigger fish feeding in deeper water with greater velocities. Henderson and Johnston (2010) observed similar ontogenetic shifts in the Cape Fear shiner: larger juvenile fish occupied locations with deeper water and higher water velocities than larvae. Similarly, Childs et al (1998) found that larger minnow and sucker larvae occupied deeper depths, but found the inverse to be the case for water velocity. Both studies attribute these shifts in habitat with increasing size to lower predation levels and a greater swimming ability of larger fishes. For larval alewives, these results indicate the need for a heterogeneous range of habitat conditions within their nursery environment to accommodate their preferred distribution during all stages of larval ontogenesis.

Size of larval fish with empty guts was not correlated with any of the microhabitat variables measured, which seemed surprising. Although it is not clear why a relationship associated with feeding was not observed, one explanation is that many of the larvae with empty guts were small fish with less locomotive ability than larger larvae and were unable to orient effectively according to water depth and current velocity. Clark et al. (2005) found that in four

species of warm-temperate marine and estuarine pelagic larvae, endurance swimming does not develop until after notochord flexion (the dorsal upturn of the notochord and caudal fin ray formation), which generally occurs when alewife are 10-12 mm in size (Walsh 2005). Alternatively, there may be associations between feeding efficiency and environmental variables that become beneficial when foraging. Capture advantages may exist for larval fish at certain depths and velocities, allowing them better chances to consume zooplankton prey.

Along with shifts in habitat, alewives also demonstrate notable feeding shifts during larval growth. Small larvae feed primarily on small prey items such as rotifers, and larger prey items become more important as alewives increase in size. Campfield and Houde (2011) detected similar diet shifts dependent on ontogeny and growth in Chesapeake Bay larval alewife. They found that copepod nauplii and rotifers represented the majority of diets in larvae less than 11 mm in length, while larger copepods and *Bosmina* were more common in larger larvae. Furthermore, Campfield and Houde (2011) observed prey preferences indicating selection for copepod nauplii and against *Bosmina* and rotifers in fish less than 10 mm in length, as well as selection for *E. affinis* copepods in fish greater than 10 mm in length. Both food quality and quantity drive foraging success, so not only the absolute abundance, but also the available size distribution is important (Crowder et al 1987; Bremigan and Stein 1994; Geffen 1996). Alewife larvae depend heavily on different prey sources as they develop, so the limited availability of even one prey item could affect larval recruitment and survival.

Zebra mussels were first detected in the Hudson River in 1991 and soon after impacted the Hudson River plankton community (Strayer et al 1999). Small zooplankton, including rotifers, tintinnids and copepod nauplii, rapidly declined by 10-20% of their pre-zebra mussel invasion levels (Pace et al 1998, Strayer et al 1999). Cladoceran densities appeared lower,

although seasonal patterns were maintained and copepods appeared least affected (Pace et al 1998). The decrease in densities of microzooplankton may have reduced the foraging ability of small alewife larvae, which consume mainly rotifers and small nauplii. Decreases in larger zooplankton could cause less or delayed feeding and reduced larval growth and size variability in larval cohorts (Geffen 1996). While zebra mussels have reduced the total density of the historical forage base, alewife larvae are consuming zebra mussel veliger larvae as well. In this study, zebra mussel veligers were frequently detected in the guts of alewives and were often the dominant prey species found in larger larvae. The nutritional value of zebra mussel veliger larvae for fish is unknown; however, bivalves passed through the gut of *Clupea harengu*s larvae largely undigested (Fossum 1983) and the mean dry weight of veligers is lower than that of cladocerans and copepods. Nevertheless, Karin Limburg (personal communication) analyzed adult zebra mussel tissue and found them to contain significant lipid content. The utilization of zebra mussel veligers as a prey source could offset the decline in other prey items if the nutritional value is comparable and if alewife larvae can effectively digest the zebra mussel veliger larvae.

An assumption of this study is that habitat variables measured at the site of capture can be associated with alewife feeding, which infers that either alewife were feeding where they were collected, or that recently fed fish were optimally positioned when captured. This is supported by the observation in another larval herring species (*C. harengus*) in which digestion of copepod nauplii and polychaete larvae was found to occur over a period of 1.5 hours, with most prey items digested within 0.5 hours (Fossum 1983). The lack of feeding in small fish could be due to faster digestion rates of smaller prey (Fossum 1983), but is likely also a function of poor swimming and resulting poor prey capture ability when larvae are small (Hunter 1981). Overall,

the feeding results found in this study are consistent with previous studies of feeding by larval herring.

Past studies have found that nutritional condition and growth of larval fish were impacted by both environmental components (temperature, wind speed, illumination) and prey availability (Esteves et al 2000; Gallego et al 1996). Fish with the highest critical swimming speeds were those that grew faster as larvae and had shorter pelagic larval durations (Grorud-Colvert and Sponaugle 2006). Furthermore, fish in better condition also exhibited less risk-taking behavior by sheltering more in the presence of a predator threat and consuming less food (Grorud-Colvert and Sponaugle 2006). In a set of alewife rearing experiments, Sismour (1994) found that starved larvae grew 0.2 mm per day versus 0.4 mm per day for feeding larvae. However, in this Hudson River study, no definitive differences in long-term growth were detected between the subsamples of ethanol-preserved recently fed fish and fish with empty guts; however, the feeding larvae tended to grow slightly faster (Table 2.2). Nevertheless, low feeding incidence does not indicate poor long-term condition for these larval fish. Perhaps the observed feeding effects were not long-term and therefore not detectable by otolith aging. A previous study found that food deprivation of American shad larvae for as little as 2 days had significant effects on survival, but growth effects were not detected until fish were starved for four days (Johnson and Dropkin 1995). Starvation could therefore have affected the behavior of larvae in the Tivoli Bays without being detectable in otoliths. While no definitive associations between growth and feeding were detected in this study, the link between condition and orientation could be particularly important in low-velocity environments where active swimming is possible.

Further investigation is necessary to determine the mechanisms for several of the trends observed in this study. The stratification of larval fish by size over water depth and water

velocity, only when feeding, is surprising and the mechanism remains unknown. Examining the mechanism responsible for this observation may provide more complete information about larval alewife behavior and may allow nursery restoration targets to account for feeding efficiency as well as habitat association. Furthermore, the nutritional value of zebra mussel veliger larvae compared to conventional prey items of similar size would provide valuable information about the impact of zebra mussels on the early life history and growth of alewives in the changed Hudson River system. Finally, the results of this study did not clarify the association between alewife feeding and growth; therefore, more information about the link between intra-habitat distribution, feeding, and growth will provide better insight regarding the mechanisms influencing larval growth and the importance of small-scale habitat heterogeneity.

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Figure 2.1. Predicted mean fish total length (TL) as a function of water depth and water velocity based on the linear model parameter estimates (Table 2.1). Depicted predictions are only for fish that have recently fed (FI=1).

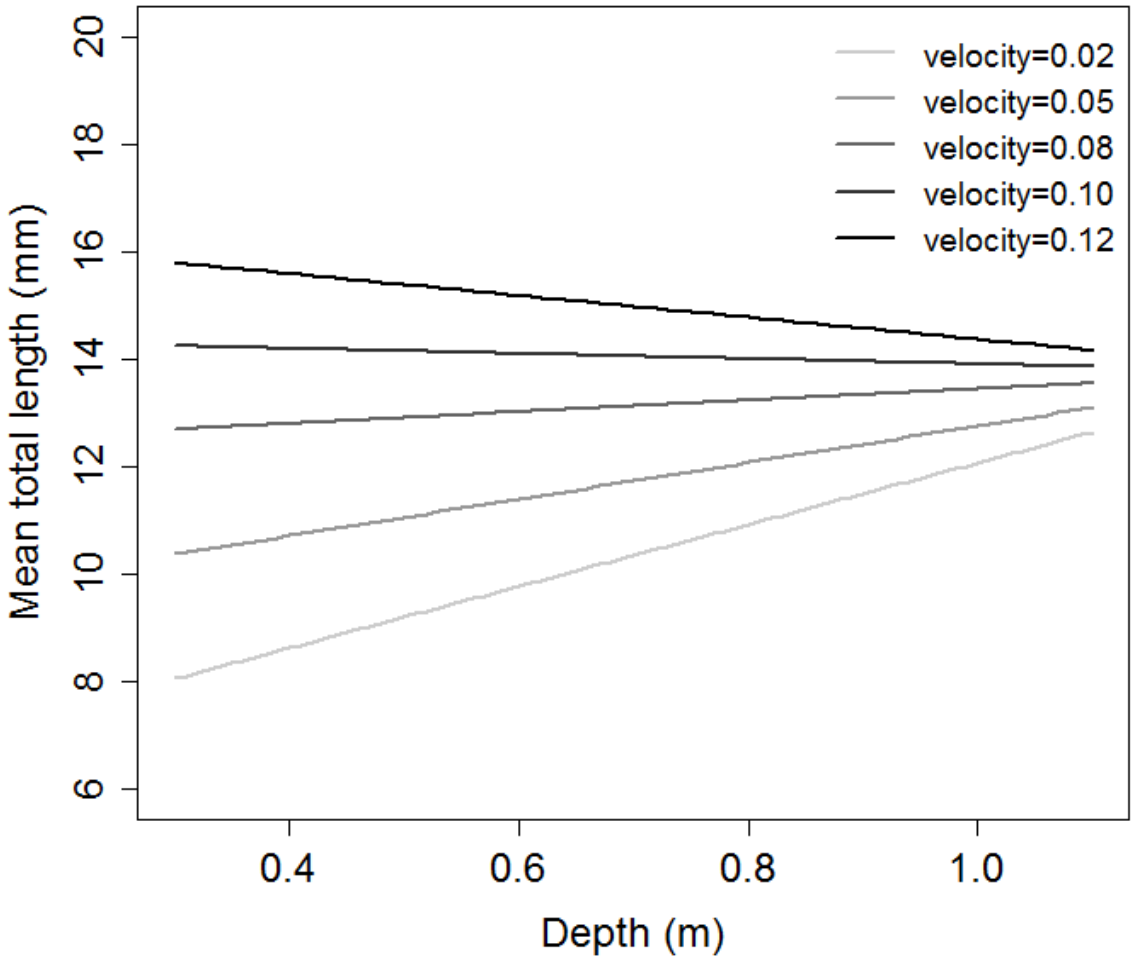

Figure 2.2. Number of prey consumed per alewife larva, represented by larval size class. Mean and standard error are shown.

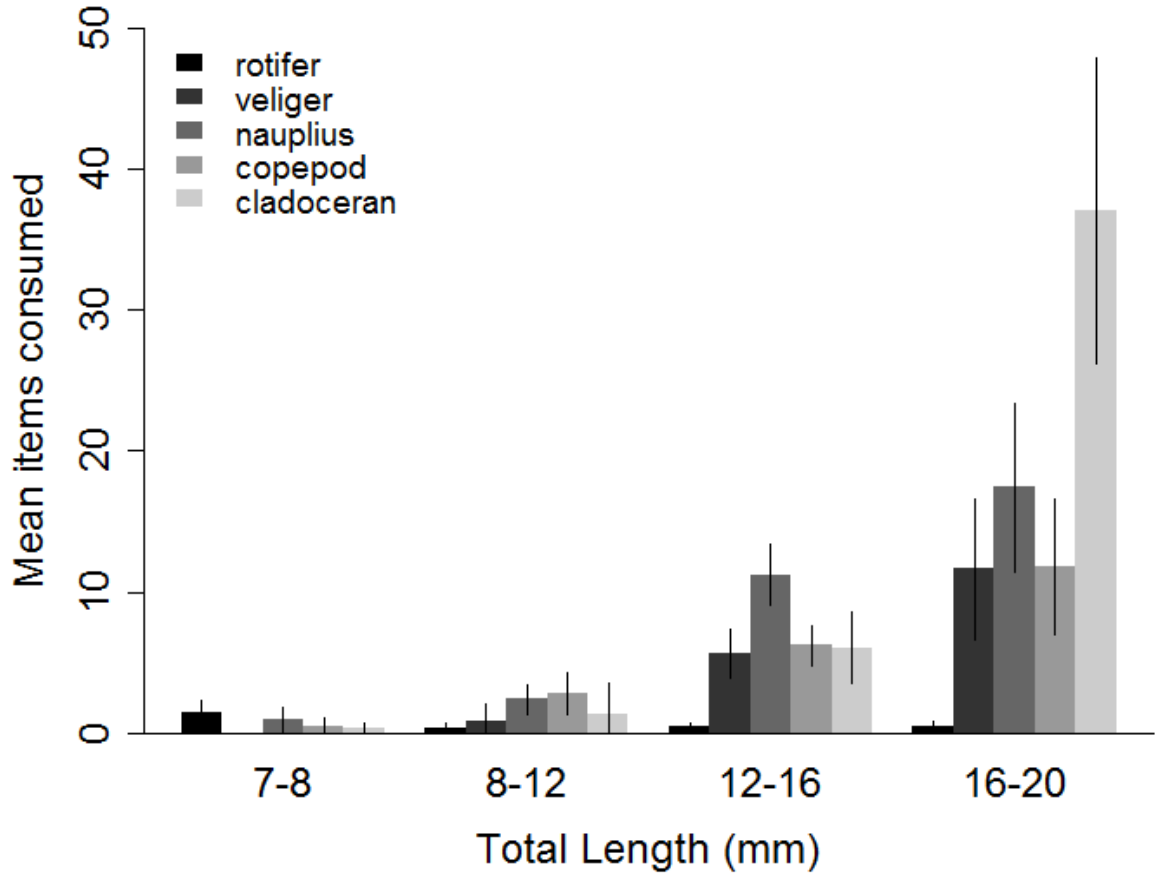

Figure 2.3. Prey biomass consumption of larval alewife according to size categories. Mean and standard error are shown.

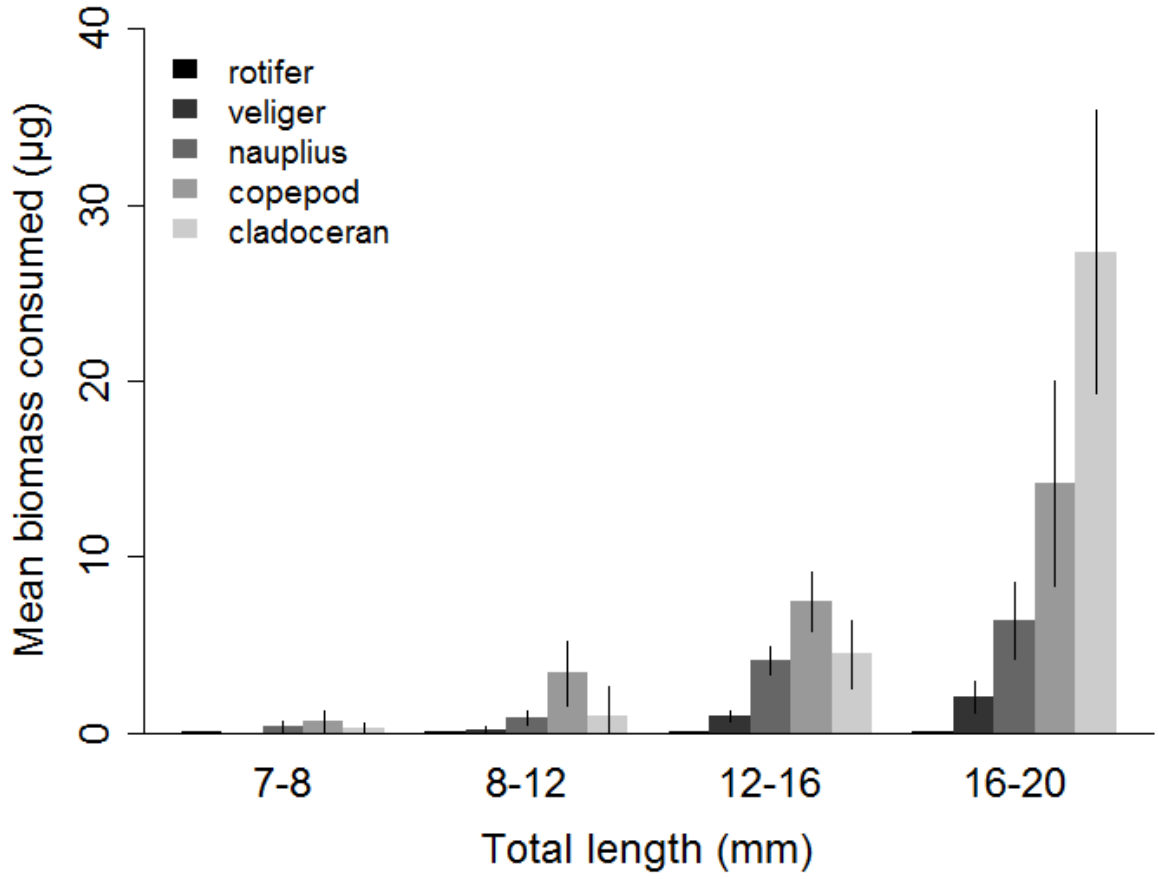

Figure 2.4. Larval alewife standard length (SL) as a function of age (days) for fish with empty guts and fish that have recently fed.

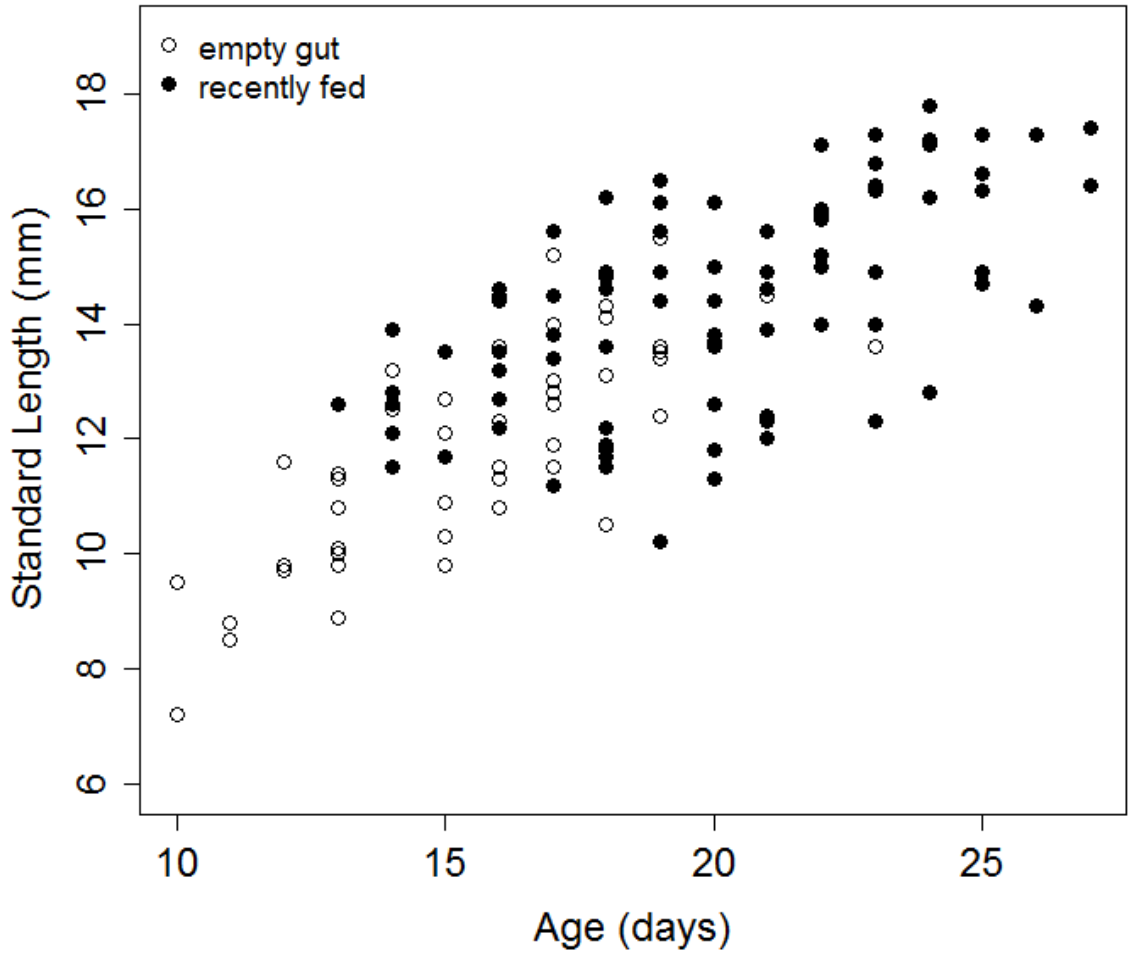

Table 2.1. Parameter estimates for the linear regression model associating alewife size (TL) with habitat variables, seasonality (degree-days), fish density, and feeding incidence. Model effect significance according to the likelihood ratio tests: t< 0.001***, t< 0.01**, t< 0.05 *, t<0.1·

Predictor	Estimate	Std. Error	t-value	Pr(>|t|)
Intercept	5.13	1.31	3.91	<0.001***
Degree-day	0.01	0.004	3.29	0.002 **
Water depth	1.68	1.88	0.89	0.37
Water velocity	31.82	17.83	1.78	0.079 ·
Feeding incidence (FI)	-2.82	1.51	-1.87	0.065 ·
Density	0.02	0.008	2.132	0.037 *
Depth * FI	5.61	1.86	3.014	0.004 **
Depth * velocity	-77.76	26.52	-2.932	0.005 **
Velocity * FI	68.96	15.38	4.485	<0.001***

Table 2.2. Parameter estimates for the linear regression model, associating alewife size (SL) with age and feeding success (0-1) using the subsample of ethanol-preserved larvae. Model effect significance according to the likelihood ratio tests: t< 0.001***, t<0.1·

Predictor	Estimate	Std. Error	t-value	Pr(>|t|)
Intercept	5.84	0.60	9.75	<0.001***
Age	0.39	0.04	10.75	<0.001***
Feeding	0.61	0.31	1.95	0.053 ·

APPENDIX A

FISH COMMUNITY COMPOSITION OF THE TIVOLI BAYS RIVER MARGINS

Introduction and Methods

The Tivoli Bays are managed by the Hudson River Estuarine Research Reserve. The bays comprise valuable habitat for tidal freshwater resident and anadromous species due to their low velocity habitat, shallow backwaters, and abundant submerged aquatic vegetation. Furthermore, these bays provide some of the few remaining large expanses of shallow water and wetland habitat remaining along the upper reaches of the estuary. Many fishes are known to reproduce and spend an important period of early life in these environments (Waldman et al 2006). A substantial amount of previous work has been conducted regarding the larval and resident fish in the Tivoli Bays (Anderson and Schmidt 1988; Limburg and Strayer 1988; Schmidt and Kiviat 1988; Bohne and Schmidt 1989; Coote et al 2001); however, none of these studies examined community fish distribution based on simultaneous assessment of multiple local habitat parameters. This appendix summarized the distribution of species of fish larvae and two groups of adults relative to one another along the outer areas of Tivoli Bays during the spring larval production months of May and June (see Figure 1.1). Its purpose was to describe habitat data in a manner that is generally applicable to understanding the Tivoli Bays fish community distribution in relation to habitat characteristics.

The relationship between larval and adult fish community composition and known variation in the mainstem Hudson River (i.e. the near-shore Tivoli Bays environment) was evaluated using canonical correspondence analysis. This multivariate technique combines aspects of regular ordination with those of direct gradient analysis to identify the environmental

basis for community ordination (Gauch 1982; Ter Braak 1986). Species groups are assumed to have a Gaussian response surface with respect to the compound environmental gradients. The first regression coefficients provided by this analysis are the canonical coefficients. The multiple correlation coefficients of the final regression provide the species-environment correlation, or how well the extracted variation in community composition can be explained by the environmental variables. The species-environment correlation (also described as the "intra-set correlation") is equal to the correlation between weighted mean species scores and a linear combination of the environmental variables.

For this analysis, densities of larval and adult fishes were analyzed in relation to a set of habitat variables defined in Chapter 1 (Table 1.1). Canonical correspondence analysis was performed using the "vegan**"** package in R statistical program (Oksanen et al 2011; R Development Core Team). CCA-based forward selection was used to determine which habitat variables to include in the most parsimonious model. Ordination axes were interpreted using the canonical coefficients and the intraset correlations. The canonical coefficients define the ordination axes as linear combinations of the environmental variables. The environmental variables were standardized to zero mean and unit variance prior to analysis to remove arbitrariness in the units of the environmental variables and make the canonical coefficients comparable to one another. This standardization infers the relative importance of each environmental variable that influences the community composition, but does not influence other aspects of the analysis (Ter Braak 1986). The plotted species points represent the species mean distributions across these environmental surfaces and the species probability of occurrence decreases with distance from this mean location in the biplot diagram.

The mean squared contingency coefficient provides the total variability (i.e., the variability explained by the model) before the matrix is subjected to weighted regression. The constrained portion of the mean squared contingency coefficient is the variability that can be explained by the ordination axes. The unconstrained portion of the mean squared contingency coefficient is the variance of the residuals of the regression. The weighted averages are approximated in the diagram as deviations from the grand mean of each environmental variable, the grand mean being represented by the origin of the plot. The length of an arrow representing an environmental variable is equal to the rate of change in the weighted average as inferred from the biplot, and is therefore a measure of how much the species distributions differ along the environmental variable (Borcard et al 2011). The biplot displays how the fish community is organized with respect to the environmental constraints.

Results and Discussion

Point habitats sampled from the mainstem areas of Tivoli Bays (Figure 1.1) cover a broad range of nursery characteristics (Table A.1). Water temperature varied with the season from cooler to warmer and exhibited a diel fluctuation. The average dissolved oxygen was 6.6 mg/l and only occasionally dropped below 4.0 mg/l. The average water depth was 0.6 meters, but ranged from very shallow (0.15 m) to moderately deep (1.12 m). Sample points were located at varying distances from shore and on substrates ranging from fine silt and detritus (coded as 1) to large pieces of riprap and boulders (coded as 5). *Trapa natans* and *Vallisneria americana* densities increased later in the season, but were generally low. By the end of June, *T. natans* stands in the bay interiors tended to be very dense.

Sampling captured 2137 fishes from 6 families. Fish were identified to family and categorized as larvae or mature and grouped by family and category (Table A.3). Fish identifications were based on taxonomic keys by Auer (1982), Kay et al (1994), and Jones et al (1978). Larval Clupeidae was represented by alewife (*Alosa pseudoharengus*), which was the most abundant fish collected (1304 individuals) and had the greatest frequency of occurrence (60%). Family Cyprinidae was mainly represented by spottail shiner (*Notropis hudsonius),* which were found frequently in small groups and occasionally in large schools (<150 fish). Cyprinids were the second most abundant group with a 33% frequency of occurrence. Moronidae captured were likely white perch (*Morone americana*) and striped bass (*Morone saxalis*). Larval Moronidae were mostly found at low densities and at a moderate frequency of occurrence (25%). Larval and mature Percidae (tessellated darter, *Etheostoma olmstedi*) and mature Fundulidae had lower frequencies of occurrence (17%, 7%, and 14% respectively). Fundulidae was mostly represented by mature banded killifish (*Fundulus diaphanous*), but mummichog (*Fundulus heteroclitus*) were also collected. Most larval Centrarchidae captured were *Lepomis* species. Legendre and Gallagher (2001) found that the abundance of common species contributes less to the chi-squared distance than the abundance of rare species, so larval Centrarchidae and Fundulidae were excluded from analysis due to their low abundances (6 and 15 fish in 2 and 8 traps, respectively). A total of six groups (larval groups: Moronidae, Percidae, Clupeidae, Cyprinidae; mature groups: mature Percidae and mature Fundulidae) from 125 samples were selected for analysis.

The forward selection procedure for the CCA resulted in the retention of six variables as significant contributors to variation in the ordination ($p<0.05$) (Table A.3). A significant correlation was found between environmental factors and species abundances along axes 1, 2, and 3 ($p<0.01$, Monte Carlo test with 1000 permutations). Together these ordinations accounted

for 38.1% of the total variance and 97.5% of the constrained variance. This indicates that while the constrained component accounts for only about a third of the observed variability, the variability explained shows strong niche separation between groups of fishes. The output diagrams show the environmental variables that best explain the patterns of variation in the community composition and provide a visual representation of the approximate centers of species distribution along each of the environmental variables. The axes can be thought of as hypothetical environmental gradients (Ter Braak, 1986). The measured environmental variables relate strongly to the first three ordination axes and are therefore sufficient to predict a large proportion of the variation in species composition (Ter Braak, 1986). Dissolved oxygen was positively correlated with the first axis, whereas water temperature and depth were negatively correlated (Table A.2). The second ordination axis was mainly driven by the negative correlation with *V. americana*, as well as secondarily by the positive correlation with coarse substrate and negative correlation with temperature. The third ordination axis was defined by its positive correlation with *T. natans* and negative correlation with distance from shore.

All six family groups showed strong niche separation, as the first three ordinations accounted for 97% of the constrained variance (Figure A.1a & A.1b). The constrained habitat variance of clupeids and cyprinids was largely explained by the first ordination: Clupeid larvae were associated with sites containing higher temperatures, lower dissolved oxygen, and deeper water depths whereas cyprinid larvae were associated with contrasting sites containing lower temperatures, higher DO, and shallower water (Table A.2). The constrained habitat variance of larval Moronidae and Percidae was largely described by the second and third ordination; both groups associated with sites containing fine substrate and higher densities of *V. americana*. Furthermore, larval Moronidae were also found further from shore and in areas with higher

densities of *T. natans*, whereas larval Percidae were found closer to shore and at locations with lower densities of *T. natans.* Habitats favored by mature Fundulidae were largely described by the first and third ordination, associated with sites further offshore containing high densities of *T. natans*, lower temperatures, deeper water depths, and higher DO. Like its larval group, mature Percidae were strongly associated with sites containing fine substrate and greater densities of *V. americana*; however, unlike their larvae, mature Percidae were found at locations with warmer temperatures, deeper water depths, further from shore, and areas with higher *T. natans* densities and lower DO.

Overall, the canonical correspondence analysis was effective at identifying differences in the fish community composition of the Tivoli Bays mainstem sites. As shown by the biplots, the most important environmental variables influencing the fish assemblage were depth, dissolved oxygen, distance from shore, substrate, temperature, and vegetation density (*T. natans* and *V. americana*). All groups of larvae and adults displayed unique environmental signatures, including the larval and mature tessellated darters (Percidae).

The Tivoli Bays fish assemblage has previously been found to be structured primarily by water depth and vegetation type (Yozzo et al 2005). This study reinforces these findings and exhibits similar family trends. Fundulids, spottail shiners, white perch, and tessellated darters have been found to prefer shallow intertidal areas, contrasting with herrings that occupy deeper channels (Schmidt 1986). Banded killifish in Tivoli South bay are one of the most abundant species in *T. natans* beds, especially when the stands become dense (Anderson and Schmidt 1988). Similarly, banded killifish are one of the dominant species in *T. natans* stands along the mainstem Tivoli Bays (Schmidt and Kiviat 1988). In contrast, alewife, other species of larval Clupeidae, and spottail shiners (Cyprinidae) were only found in low-density vegetation and were

no longer present after stands became dense (Schmidt and Kiviat 1988; Anderson and Schmidt 1988).

In addition to depth and vegetation presence, structural and physiochemical variables such as substrate size, distance from shore, temperature and DO exhibited a significant influence upon the structure of the Tivoli Bays fish community. These factors were also observed as influencing the fish communities within other rivers (Garner 1995; Scheidegger and Bain 1995; Sarkar and Bain 2007; Dubey et al 2012). Temperature is often dictated by seasonal changes and is an important driver of spawning and larval fish growth (Werner 2002). Similarly, dissolved oxygen has also been found to affect larval growth and species vary in their degree of anoxia tolerance (Werner 2002). Substrate size and distance from shore have been associated with larval feeding and predator avoidance because structure provides hiding places for small fish and shallow, near-shore areas are less accessible to predators (Scheidegger and Bain 1995; Childs et al 1998; Garner 1995).

This study utilized canonical correspondence analysis as a habitat association technique to differentiate habitat use of the Tivoli Bays mainstem fish community over families and life stages. Results from this investigation add to the extensive body of information regarding the Tivoli Bays fish community and illustrate a method for comprehensive community comparison. This type of comparison may be important when considering changes to shallow water habitat in the future, either for the rehabilitation of former nursery areas or the development of shoreline habitats.

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Figure A.1a. Canonical correspondence analysis ordination diagram (biplot) of the first two ordination axes. Habitat gradients are represented by blue arrows and family group weighted averages are represented by the positions of the red group labels. Family group and habitat label identifications are found in Tables A.1 and A.3.

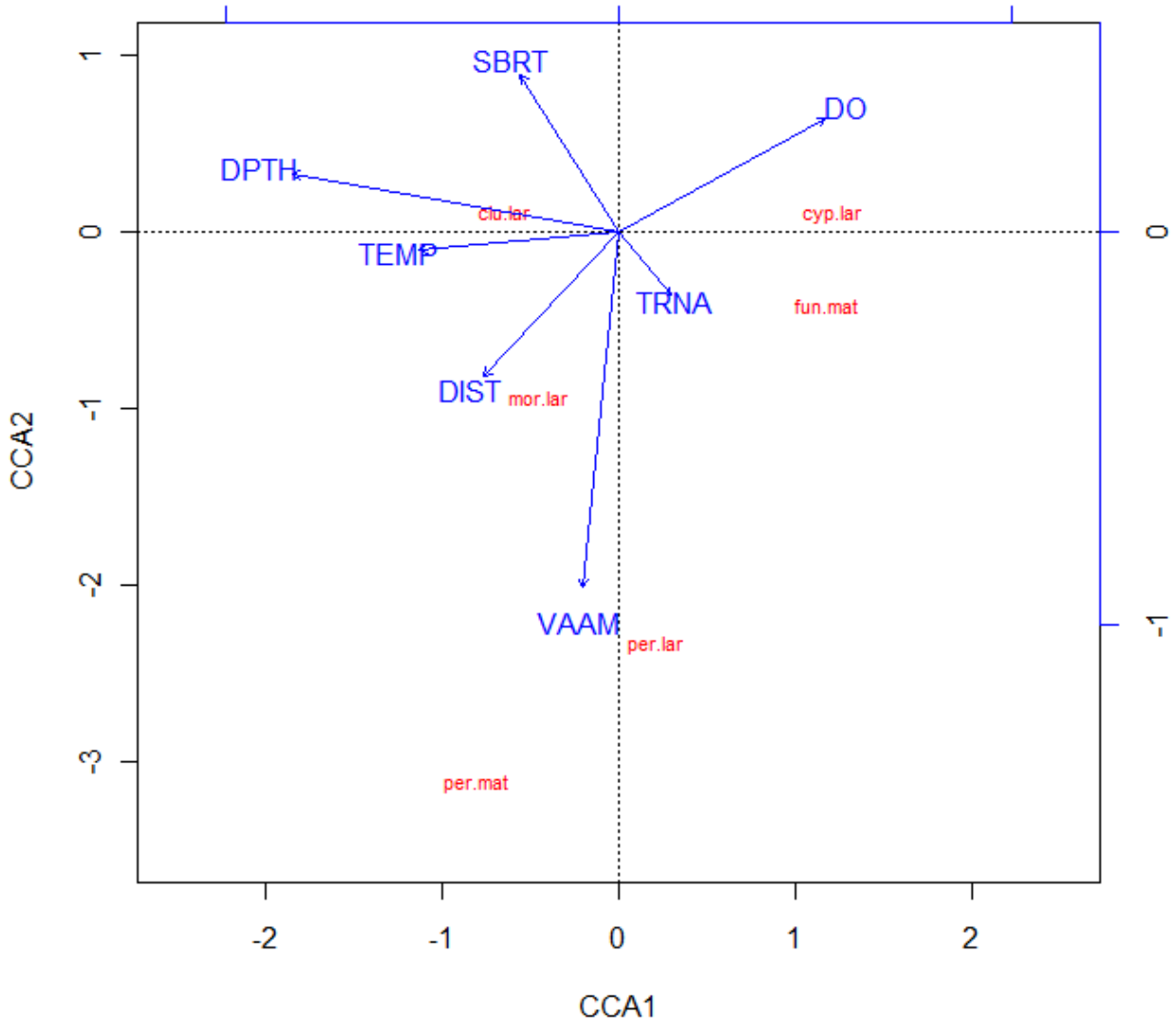

Figure A.1b. Canonical correspondence analysis ordination diagram (biplot) of the first and third ordination axes. Habitat gradients are represented by blue arrows and family group weighted averages are represented by the positions of the red group labels. Family group and habitat label identifications are found in Tables A.1 and A.3.

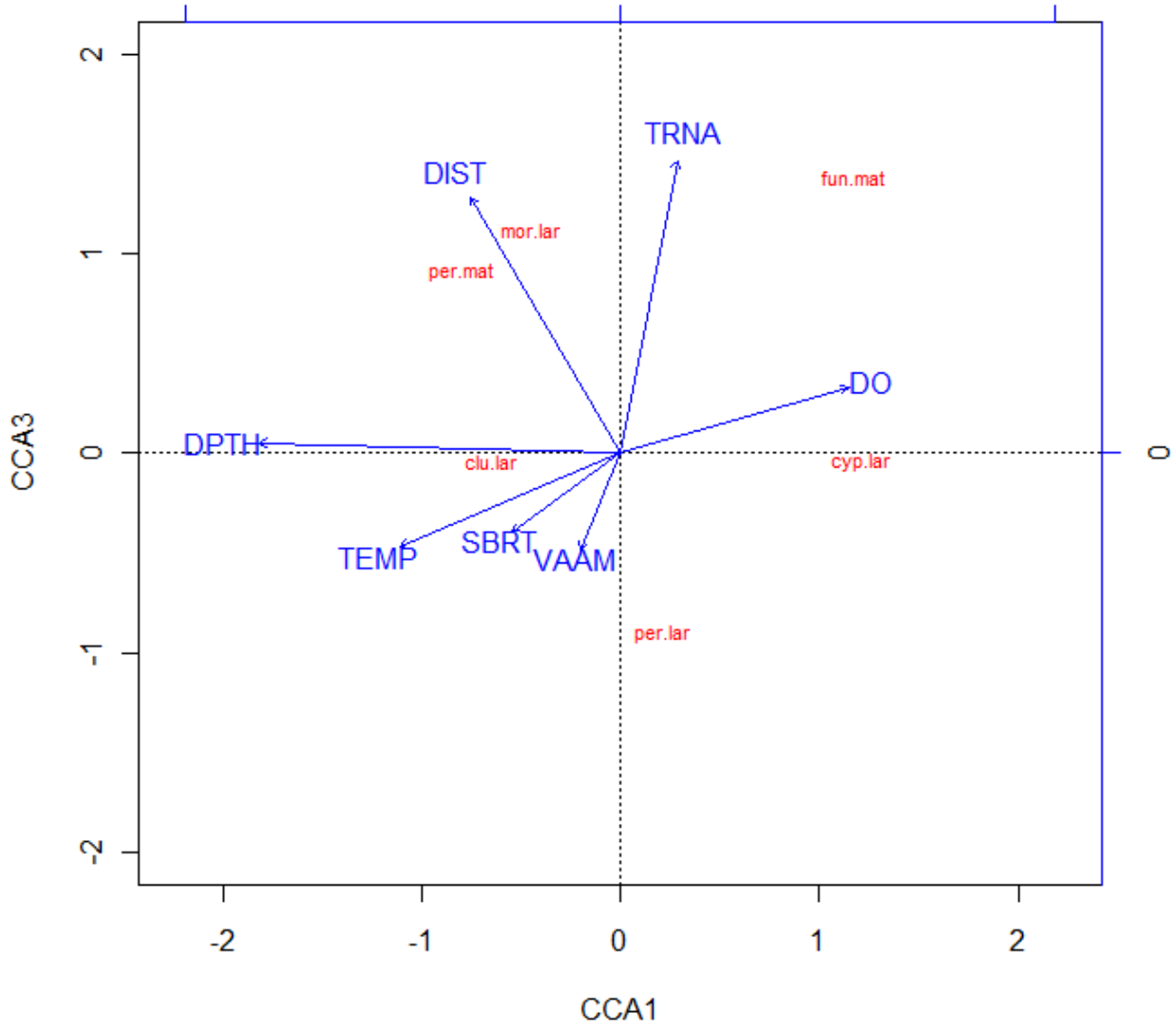

Table A.1. Mean (standard deviation) and range of the environmental variables included in the most parsimonious model, collected from 125 sampling sites in the Tivoli Bays, NY. For a complete description of terms and collection, see Chapter 1 and Table 1.1 of this thesis.

Variable	Label	Mean	(SD)	Range
Water temperature (°C)	TEMP	23.1	(1.5)	18.8 - 27.3
Dissolved oxygen (mg/l)	DO	6.6	(1.7)	2.2 - 9.3
Water depth (m)	DPTH	0.6	(0.3)	0.15 - 1.12
Distance from shore (m)	DIST	7.0	(7.2)	0.4 - 39.4
Substrate (coded)	SBRT	2.2	(1.1)	1 - 5
Trapa natans (%)	TRNA	3.2	(12.4)	0 - 80
Vallisneria americana (%)	VAAM	1.4	(4.7)	0 - 25

Table A.2. Family group divisions, frequency of occurrence, and family group scores along the first three ordination axes.

Family group	Label	Freq Occur	Axis 1	Axis 2	Axis 3
Larval Clupeidae	clu.lar	0.60	-0.64	0.11	-0.03
Larval Cyprinidae	cyp.lar	0.33	1.21	0.10	-0.03
Larval Moronidae	mor.lar	0.25	-0.44	-0.93	1.12
Larval Percidae	per.lar	0.17	0.21	-2.33	-0.89
Mature Fundulidae	fun.mat	0.14	1.17	-0.41	1.38
Mature Percidae	per.mat	0.07	-0.80	-3.12	0.91

Table A.3. Canonical correspondence analysis summary statistics for the fish and environment sampled in Tivoli Bays, NY. Environment scores represent the first three ordination axes. Intraset correlation identifiers are described in Table A.1.

	Axis 1	Axis 2	Axis 3
Eigenvalues	0.75	0.22	0.09
Species-environment correlation	0.89	0.60	0.40
Cumulative percentage variance	0.27	0.35	0.38
Interset correlations			
TEMP	-0.51	-0.47	-0.21
DO	0.52	0.29	0.15
DPTH	-0.83	0.15	0.02
DIST	-0.34	-0.37	0.59
SBTR	-0.25	0.40	-0.18
TRNA	0.13	-0.16	0.67
VAAM	-0.09	-0.90	-0.22

APPENDIX B

SUMMARY OF STUDY DATA

This summary contains three tables of data utilized in this study. All larval and adult fishes were captured from May-July, 2011 in Tivoli Bays, New York.

Table A.4 lists the habitat variables and number of larval and adult fishes collected for each throw trap sample. Values listed are the individual trap identifier (trapID), date, time, site, temperature (temp, °C), dissolved oxygen (DO, mg/l), turbidity (turb, NTU), river water depth (wd, m), tidal change in water level (chg, m/hr), degree-day (dd), latitude (lat), longitude (long), sample water depth (depth, m), sample water velocity (vel, m/sec), maximum water velocity (maxvel, m/sec), distance from shore (dfs, m), substrate composition in percentage (silt, sand, gravel, cobble, boulder) coded substrate score (subcode) % vegetation density (vegcover) % Trapa natans (TRNA), % Nuphar lutea (NULU), %Vallisneria americana (VAAM), and numbers of fish collected from the following family groups: larval Clupeidae (clu), larval Cyprinidae (cyp), larval Moronidae (mor), larval Centrarchidae (cen), larval Fundulidae (fun), larval Percidae (per), mature Fundulidae (funmat), and mature Percidae (permat). The values for temperature, dissolved oxygen, turbidity, and river water depth were obtained from the Hudson River National Estuarine Research Reserve gauges located in the Tivoli Bays (NOAA).

Table A.5 lists the prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin. Values listed are the individual trap identifier (trapID), total length (TL), *Halicyclops*, *Diacyclops thomasi*, *Eurytemora affinis*, unknown copepod (UK cop), *Daphnia*, *Bosmina freyii*, *Leptodora kinditii*, unknown Bosmina (UK Bosmina), *Diaphanosoma*, nauplius, rotifer, veliger, and unknown (UK).

Table A.6 lists the total length, age, body measurements, and gut state for the individual alewife larvae preserved in 90% ethanol. Values listed are the individual trap identifier (trapID), age in days, determined from sagittal otolith ring counts (age), total length (TL), standard length (SL) head width (head) pelvic body depth (PBD), anal body depth (ABD), and gut state (gut, 0: empty, 1: one or more prey item present).

Table A.4. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	date	time	site	temp	DO	turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
101	6/9/2011	11:16	MI	24.0	5.6	-4.0	0.85	-0.23	88.6	42.04421	-73.92698	0.80	0.12	0.12	19.6	90
104	6/9/2011	10:55	MI	23.8	5.3	-4.0	0.93	-0.26	88.6	42.0442	-73.92727	0.55	0.03	0.03	4.9	20
120	6/1/2011	8:13	MI	22.4	4.2	3.0	0.43	0.04	41.6	42.04677	-73.92619	0.20	0.16	0.16	1.6	0
123	6/1/2011	9:10	MI	22.7	5.1	5.0	0.52	0.15	41.6	42.04547	-73.92639	0.66	0.05	0.13	3.4	40
124	6/1/2011	9:50	MI	22.7	7.7	12.0	0.69	0.26	41.6	42.04689	-73.92672	0.56	0.01	0.12	6.16	100
125	6/1/2011	10:10	MI	22.8	8.1	20.0	0.78	0.27	41.6	42.04594	-73.92613	1.01	0.01	0.08	17.3	100
126	6/1/2011	10:26	MI	22.8	8.2	30.0	0.89	0.41	41.6	42.04599	-73.92627	1.00	0.02	0.08	6.9	0
127	6/1/2011	10:56	MI	22.9	8.4	20.0	1.06	0.34	41.6	42.04671	-73.92619	0.69	0.04	0.15	10.1	100
130	6/1/2011	8:50	MI	22.7	4.5	4.0	0.47	0.10	41.6	42.04596	-73.92628	1.00	0.1	0.10	7.7	50
128	6/9/2011	13:30	MI	25.2	4.0	-11.0	0.36	-0.23	88.6	42.04562	-73.92635	1.10	0.12	0.10	7.9	10
129	6/1/2011	11:14	MI	22.9	8.3	15.0	1.13	0.23	41.6	42. 04690	-73.92615	0.55	0.03	0.10	2.2	45
139	6/1/2011	11:45	MI	23.0	8.4	12.0	1.26	0.25	41.6	42.04647	-73.92632	0.80	0.04	0.05	6.8	80
140	6/1/2011	11:58	MI	22.9	8.4	11.0	1.31	0.23	41.6	42.04621	-73.92638	0.67	0.04	0.11	1.3	0
143	6/1/2011	12:15	MI	23.0	8.5	13.0	1.36	0.18	41.6	42.04656	-73.92628	0.35	0.07	0.07	1.4	0
144	6/6/2011	12:19	MI	22.8	6.5	1.0	0.32	0.21	68.0	42.04505	-73.92662	0.23	0.04	0.18	1.61	20
145	6/6/2011	12:41	MI	23.7	8.1	2.0	0.40	0.22	68.0	42.04499	-73.92659	0.55	0.06	0.16	4.77	30
148	6/6/2011	13:03	MI	23.2	6.9	-5.0	0.5	0.27	68.0	42.04628	-73.92623	0.47	0.03	0.07	9.4	100
151	6/6/2011	14:31	MI	22.2	8.3	5.0	0.99	0.35	68.0	42.04512	-73.92657	0.19	0.05	0.05	1.55	0
153	6/6/2011	14:56	MI	21.9	8.2	4.0	1.15	0.38	68.0	42.04742	-73.92629	0.34	0.03	0.07	1.2	0
155	6/6/2011	15:22	MI	21.8	8.2	9.0	1.24	0.21	68.0	42.0453	-73.92645	0.70	0.02	0.10	3	0
156	6/6/2011	14:05	MI	22.5	8.4	7.0	0.84	0.30	68.0	42.04499	-73.9266	0.86	0.07	0.16	8.1	30
159	6/6/2011	16:27	MI	21.7	8.1	6.0	1.44	0.14	68.0	42.04458	-73.92691	0.68	0.06	0.10	3.4	65
160	6/6/2011	15:58	MI	21.8	8.2	5.0	1.37	0.23	68.0	42.04628	-73.92638	0.43	0.02	0.13	1.9	0
162	6/1/2011	8:32	MI	22.7	5.0	26.0	0.44	0.03	41.6	42.04441	-73.92679	0.25	0.05	0.12	10.51	100
164	6/6/2011	15:40	MI	21.8	8.2	9.0	1.30	0.20	68.0	42.04554	-73.92644	0.36	0.03	0.12	1.3	0
168	6/6/2011	16:51	MI	21.8	8.1	4.0	1.47	0.08	68.0	42.04445	-73.92696	0.94	0.09	0.11	11	100
169	6/9/2011	9:35	MI	23.0	6.4	-2.0	1.27	-0.20	88.6	42.04651	-73.92638	0.72	0.05	0.05	3	0
171	6/9/2011	13:06	MI	25.2	4.8	-8.0	0.45	-0.14	88.6	42.04533	-73.92648	0.43	0.08	0.08	1.4	0
172	6/9/2011	14:29	MI	26.8	4.6	-17.0	0.34	0.05	88.6	42.04419	-73.92692	0.16	0.03	0.12	6.9	100
173	6/9/2011	11:37	MI	24.2	5.7	-1.0	0.75	-0.29	88.6	42.04399	-73.92731	0.74	0.05	0.05	19.6	100

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	date	time	site	temp	DO	turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
175	6/9/2011	12:45	MI	25.3	5.3	-6.0	0.5	-0.26	88.6	42.044	-73.9273	0.42	0.03	0.04	16.6	100
177	6/9/2011	10:32	MI	23.5	5.4	-3.0	1.03	-0.28	88.6	42.04405	-73.92751	0.55	0.01	0.01	1.7	0
178	6/9/2011	13:55	MI	26.7	5.1	-11.0	0.31	-0.12	88.6	42.04689	-73.92612	0.45	0.03	0.08	8.05	100
179	6/9/2011	12:29	MI	24.9	5.2	-4.0	0.57	-0.21	88.6	42.04399	-73.9272	0.64	0.18	0.18	29.8	100
181	6/6/2011	13:21	MI	22.8	7.6	-1.0	0.62	0.40	68.0	42.04438	-73.92676	0.50	0.04	0.10	5	100
185	6/9/2011	10:02	MI	23.3	5.7	1.0	1.17	-0.22	88.6	42.04509	-73.92659	0.78	0.26	0.26	2.8	0
190	6/2/2011	12:14	CI	22.5	8.7	12.0	0.96	0.33	47.7	42.02776	-73.92792	0.23	0.02	0.03	2.4	25
191	6/2/2011	13:03	CI	22.5	8.6	11.0	1.11	0.18	47.7	42.0279	-73.72778	0.24	0.06	0.06	1.75	30
192	6/2/2011	11:50	CI	22.6	8.8	10.0	0.83	0.30	47.7	42.02961	-73.92702	0.28	0.02	0.03	6	100
196	6/2/2011	11:28	CI	22.5	8.7	11.0	0.72	0.28	47.7	42.02912	-73.9262	0.31	0.02	0.04	6.15	100
197	6/2/2011	10:06	CI	22.4	8.7	16.0	0.34	0.24	47.7	42.02789	-73.9302	0.48	0.02	0.01	3.65	100
198	6/2/2011	14:07	CI	22.6	8.5	4.0	1.12	-0.08	47.7	42.04812	-73.92819	0.88	0.04	0.04	11.2	100
199	6/2/2011	8:31	CI	22.1	8.0	24.0	0.21	0.31	47.7	42.02789	-73.9263	0.57	0.05	0.05	8.35	100
200	6/2/2011	9:03	CI	22.3	8.4	28.0	0.17	-0.08	47.7	42.02832	-73.92632	0.34	0.01	0.05	9.8	100
201	6/2/2011	9:38	CI	22.3	8.5	19.0	0.23	0.24	47.7	42.02732	-73.92852	0.15	0.04	0.04	16.45	100
203	6/8/2011	10:02	CI	23.3	6.8	13.0	0.69	-0.24	81.1	42.02769	-73.92872	0.89	0.02	0.03	30.2	100
204	6/8/2011	9:29	CI	23.1	6.8	10.0	0.82	-0.20	81.1	42.02783	-73.92791	0.43	0.03	0.03	2.4	90
205	6/8/2011	10:21	CI	23.6	6.6	17.0	0.60	-0.28	81.1	42.02801	-73.93021	0.68	0.01	0.01	3.7	100
206	6/8/2011	10:46	CI	23.9	6.9	7.0	0.5	-0.24	81.1	42.02811	-73.92929	0.66	0.01	0.03	19.6	100
207	6/8/2011	12:30	CI	25.9	7.7	16.0	0.06	-0.24	81.1	42.02739	-73.9264	0.88	0.03	0.05	14	100
208	6/8/2011	11:21	CI	24.7	7.6	11.0	0.32	-0.31	81.1	42.0282	-73.92621	0.35	0.05	0.05	1.95	0
209	6/8/2011	11:33	CI	24.8	7.7	13.0	0.29	-0.15	81.1	42.02851	-73.92625	0.70	0.03	0.05	1.4	50
213	6/2/2011	14:35	CI	22.7	8.9	10.0	1.06	-0.13	47.7	42.02837	-73.92937	0.26	0.02	0.03	1.5	80
215	6/8/2011	13:07	CI	27.1	8.9	11.0	-0.04	-0.16	81.1	42.02712	-73.92852	0.14	0	0.03	4	100
216	6/8/2011	13:23	CI	27.3	8.9	11.0	-0.05	-0.04	81.1	42.02802	-73.92998	0.22	0.01	0.01	16.5	100
217	6/8/2011	13:51	CI	27.3	8.8	13.0	0.02	0.15	81.1	42.02769	-73.93019	0.59	0.03	0.03	6.9	100
245	6/8/2011	14:35	CI	26.5	9.3	15.0	0.20	0.25	81.1	42.02679	-73.92911	0.58	0.04	0.04	8.1	100
252	6/8/2011	14:55	CI	25.0	9.0	18.0	0.36	0.48	81.1	42.02788	-73.92751	0.13	0.01	0.04	3.6	100
269	6/2/2011	13:27	CI	22.5	8.5	7.0	1.15	0.10	47.7	42.02731	-73.92816	0.81	0.04	0.04	6.8	100
271	6/2/2011	13:43	CI	22.5	8.5	8.0	1.15	0.00	47.7	42.02791	-73.92871	0.89	0.06	0.06	12.9	100

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

NumID	date	time	Site	Temp	DO	Turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
311	5/31/2011	15:26	RR	25.3	9.1	14.0	0.87	-0.23	34.2	42.04631	-73.9251	0.81	0.08	0.10	2.1	0
312	5/31/2011	14:07	RR	23.7	9.0	26.0	1.14	-0.18	34.2	42.04716	-73.92503	0.78	0.02	0.02	2.5	0
314	5/31/2011	16:22	RR	26.1	9.1	14.0	0.74	-0.14	34.2	42.04634	-73.92516	0.97	0.17	0.17	6.6	100
315	5/31/2011	15:02	RR	24.8	9.0	13.0	0.96	-0.20	34.2	42.04751	-73.925	0.57	0.02	0.02	3.8	0
316	6/7/2011	12:55	RR	23.7	4.2	-6.0	0.35	0.00	74.1	42.04713	-73.92512	0.66	0.08	0.08	2.7	100
318	6/7/2011	13:17	RR	23.6	4.1	-5.0	0.4	0.14	74.1	42.04648	-73.92511	0.32	0.13	0.13	1.1	10
320	6/7/2011	15:15	RR	22.5	8.1	6.0	1.04	0.42	74.1	42.04601	-73.92519	0.79	0.06	0.07	7.3	100
321	6/10/2011	9:47	RR	23.3	6.8	9.0	1.48	-0.64	96.2	42.04761	-73.92496	0.39	0.05	0.05	0.65	0
322	6/10/2011	12:22	RR	24.1	5.2	-2.0	0.66	-0.23	96.2	42.04588	-73.92513	0.73	0.14	0.14	2.1	0
323	6/10/2011	11:02	RR	23.4	5.6	4.0	0.98	-0.28	96.2	42.0464	-73.92506	1.11	0.01	0.02	2.7	0
325	6/10/2011	12:01	RR	23.8	5.2	-3.0	0.74	-0.24	96.2	42.04598	-73.92533	0.94	0.11	0.11	11.1	100
328	5/31/2011	13:44	RR	23.1	8.9	41.0	1.21	-0.12	34.2	42.04678	-73.92505	0.94	0.06	0.06	3.15	0
333	5/31/2011	13:24	RR	22.9	8.8	47.0	1.25	-0.06	34.2	42.04392	-73.92527	1.24	0.07	0.09	3.8	0
342	6/7/2011	14:53	RR	22.7	8.1	2.0	0.90	0.41	74.1	42.04521	-73.92519	1.04	0.11	0.11	3.9	60
343	6/7/2011	11:18	RR	22.4	5.9	1.0	0.47	-0.24	74.1	42.04395	-73.92529	0.92	0.17	0.17	3.8	90
345	5/25/2011	12:37	RR	19.0	7.6	18.0	0.73	#N/A	3.6	42.04553	-73.9252	0.47	0.06	0.09	2.4	0
346	6/7/2011	12:01	RR	22.7	5.1	-5.0	0.35	-0.14	74.1	42.04538	-73.92529	0.72	0.11	0.11	12.1	60
348	6/7/2011	11:32	RR	22.4	5.8	2.0	0.42	-0.21	74.1	42.04508	-73.92519	0.82	0.08	0.13	2.1	20
349	6/7/2011	15:05	RR	22.7	8.1	2.0	0.97	0.35	74.1	42.04507	-73.92519	1.07	0.14	0.14	4	20
350	6/10/2011	10:36	RR	23.3	5.7	7.0	1.10	-0.26	96.2	42.04386	-73.92528	0.64	0.02	0.09	1.05	0
351	6/10/2011	10:13	RR	23.2	6.0	15.0	1.2	-0.65	96.2	42.04469	-73.92519	0.44	0.03	0.08	1	0
352	6/10/2011	13:18	RR	24.5	4.9	-4.0	0.46	-0.21	96.2	42.04437	-73.92525	0.96	0.2	0.20	2.85	60
354	6/10/2011	13:32	RR	24.6	4.8	-8.0	0.41	-0.21	96.2	42.04428	-73.92525	0.78	0.12	0.12	1.3	0
368	6/10/2011	13:47	RR	24.6	4.7	-9.0	0.37	-0.16	96.2	42.04204	-73.92539	0.45	0.04	0.04	3.4	0
369	6/10/2011	14:21	RR	24.8	3.5	-10.0	0.28	-0.15	96.2	42.04278	-73.92535	0.19	0.04	0.10	0.6	10
371	6/7/2011	14:34	RR	23.0	8.1	9.0	0.77	0.23	74.1	42.0407	-73.92551	0.75	0.03	0.03	6.3	100
374	5/31/2011	13:03	RR	22.7	8.6	27.0	1.27	-0.02	34.2	42.04307	-73.92532	0.97	0.09	0.14	3.2	0
375	5/31/2011	12:37	RR	22.6	8.6	21.0	1.28	-0.02	34.2	42.04263	-73.92532	0.91	0.06	0.10	1.15	0
377	6/7/2011	14:13	RR	23.1	7.9	0.0	0.69	0.36	74.1	42.0423	-73.92537	0.33	0.04	0.08	1.6	0
378	6/7/2011	10:48	RR	21.9	5.9	4.0	0.59	-0.25	74.1	42.04169	-73.92541	0.68	0.07	0.07	3.9	20

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	date	time	site	temp	DO	turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
379	6/7/2011	13:40	RR	23.9	6.8	-3.0	0.49	0.23	74.1	42.04161	-73.92548	0.45	0.01	0.06	7.3	100
387	6/10/2011	14:36	RR	24.9	3.7	-11.0	0.26	-0.08	96.2	42.04309	-73.92538	0.38	0.09	0.14	3	100
389	6/10/2011	14:09	RR	24.6	3.8	-9.0	0.31	-0.16	96.2	42.04058	-73.9255	0.49	0.05	0.05	1.7	30
400	6/15/2011	11:54	MI	21.8	7.5	-1.0	1.46	0.22	124.8	42.04677	-73.92623	0.41	0.07	0.10	1.5	0
401	6/15/2011	9:05	MI	19.9	5.6	2.0	0.52	0.36	124.8	42.04701	-73.92616	0.30	0.07	0.13	3.7	100
402	6/15/2011	12:40	MI	21.9	7.5	-3.0	1.57	0.14	124.8	42.04539	-73.92651	0.77	0.01	0.11	3.5	0
403	6/15/2011	13:03	MI	22.0	7.4	-5.0	1.61	0.10	124.8	42.04657	-73.92635	0.81	0.02	0.05	3	0
404	6/15/2011	9:25	MI	20.5	6.3	1.0	0.64	0.36	124.8	42.04581	-73.92629	0.84	0.02	0.08	7.8	30
405	6/15/2011	9:59	MI	21.4	7.4	3.0	0.84	0.35	124.8	42.04733	-73.92618	0.32	0.07	0.07	3.2	0
406	6/15/2011	10:14	MI	21.5	7.5	1.0	0.94	0.40	124.8	42.04608	-73.92633	0.70	0.02	0.08	3.5	0
407	6/15/2011	10:35	MI	21.7	7.5	12.0	1.07	0.37	124.8	42.04531	-73.92641	1.06	0.11	0.11	7.5	0
409	6/15/2011	11:43	MI	21.9	7.6	-1.0	1.42	0.24	124.8	42.04651	-73.92631	1.08	0.02	0.06	12	100
410	6/15/2011	12:09	MI	21.9	7.5	-1.0	1.50	0.16	124.8	42.04424	-73.92723	0.80	0.22	0.22	0.85	0
413	6/15/2011	13:23	MI	22.1	7.1	-5.0	1.61	0.00	124.8	42.04479	-73.92672	0.49	0.05	0.11	3.2	0
417	6/27/2011	17:04	MI	25.7	3.9	15.0	0.47	0.06	203.3	42.04533	-73.92641	1.12	0.03	0.11	9.6	20
420	6/22/2011	12:26	MI	22.3	3.5	1.0	0.39	-0.04	170.8	42.0449	-73.92667	0.64	0.12	0.13	3.7	20
421	6/22/2011	12:39	MI	22.3	3.1	0.0	0.38	-0.05	170.8	42.04629	-73.92628	0.78	0.06	0.08	5.7	40
422	6/27/2011	14:30	MI	24.8	6.3	20.0	0.74	-0.15	203.3	42.04658	-73.9264	0.31	0.07	0.07	1.4	10
423	6/22/2011	12:50	MI	22.3	3.5	-1.0	0.37	-0.05	170.8	42.04752	-73.92632	0.36	0.03	0.07	2.1	0
424	6/22/2011	13:03	MI	22.4	2.5	-6.0	0.36	-0.05	170.8	42.04649	-73.92621	0.37	0.03	0.08	12.4	100
425	6/22/2011	13:24	MI	22.5	2.3	-4.0	0.40	0.11	170.8	42.04394	-73.92761	0.28	0.08	0.08	2.3	40
426	6/22/2011	14:01	MI	22.5	3.6	-7.0	0.51	0.18	170.8	42.04595	-73.92628	0.73	0.03	0.08	5.2	30
427	6/22/2011	14:14	MI	22.7	4.4	-6.0	0.57	0.28	170.8	42.04731	-73.92616	0.27	0.04	0.07	1.7	0
428	6/22/2011	14:42	MI	22.9	6.8	-4.0	0.69	0.26	170.8	42.04752	-73.92634	0.36	0.05	0.08	1.2	0
429	6/22/2011	14:57	MI	23.0	7.6	-3.0	0.75	0.24	170.8	42.04491	-73.9267	0.55	0.03	0.13	2.8	0
430	6/15/2011	10:58	MI	21.8	7.6	2.0	1.24	0.44	124.8	42.04574	-73.9263	0.46	0.01	0.09	1.4	0
431	6/27/2011	16:11	MI	24.9	4.5	14.0	0.49	-0.09	203.3	42.04469	-73.92667	0.26	0.18	0.19	1.5	30
433	6/22/2011	15:13	MI	23.0	7.6	-1.0	0.83	0.30	170.8	42.04567	-73.92631	1.21	0.05	0.10	9.4	10
434	6/27/2011	13:14	MI	23.8	7.3	15.0	0.93	-0.15	203.3	42.04713	-73.92622	0.93	0.03	0.10	7.5	75
436	6/22/2011	15:48	MI	23.0	7.7	-2.0	0.98	0.23	170.8	42.04608	-73.92635	1.11	0.03	0.08	6.8	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	date	time	site	temp	DO	turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
437	6/27/2011	16:24	MI	25.0	4.0	16.0	0.47	-0.09	203.3	42.0448	-73.92659	0.94	0.07	0.12	13.1	30
440	6/27/2011	15:57	MI	24.9	5.0	16.0	0.51	-0.12	203.3	42.04562	-73.92632	0.95	0.04	0.12	6.9	0
441	6/27/2011	15:24	MI	25.1	5.6	22.0	0.58	-0.17	203.3	42.04458	-73.9267	0.73	0.23	0.23	8.8	0
442	6/27/2011	16:43	MI	25.6	4.6	18.0	0.45	-0.06	203.3	42.04718	-73.9261	0.69	0.01	0.10	15.2	100
443	6/27/2011	15:31	MI	25.1	5.6	22.0	0.57	-0.09	203.3	42.04449	-73.9267	0.96	0.23	0.23	19.4	40
444	6/27/2011	14:47	MI	24.9	6.0	21.0	0.7	-0.14	203.3	42.0451	-73.92669	0.56	0.12	0.15	2.1	0
446	6/27/2011	14:56	MI	25.0	5.9	21.0	0.66	-0.27	203.3	42.04489	-73.9267	0.89	0.12	0.13	5.6	0
448	6/22/2011	15:27	MI	23.0	7.7	-7.0	0.9	0.30	170.8	42.04649	-73.92635	0.35	0.07	0.07	2.9	100
449	6/27/2011	15:47	MI	25.0	5.3	21.0	0.53	-0.15	203.3	42.04469	-73.92669	0.32	0.23	0.23	1.9	30
551	6/17/2011	11:14	RR	22.0	6.8	5.0	0.78	0.26	136.8	42.0467	-73.92511	1.05	0.07	0.07	3.7	50
552	6/21/2011	12:06	RR	22.9	4.2	-5.0	0.34	-0.09	163.8	42.04198	-73.9254	0.35	0.03	0.04	1	0
553	6/17/2011	11:33	RR	22.1	7.1	10.0	0.87	0.28	136.8	42.04712	-73.92508	0.31	0.06	0.06	1.15	0
554	6/17/2011	12:47	RR	22.4	7.4	-2.0	1.32	0.20	136.8	42.0464	-73.92509	0.64	0.05	0.11	1.85	0
555	6/17/2011	12:26	RR	22.3	7.4	0.0	1.25	0.45	136.8	42.04361	-73.92529	0.95	0.16	0.16	3.1	0
556	6/17/2011	12:10	RR	22.4	7.4	-3.0	1.13	0.30	136.8	42.04479	-73.92523	0.98	0.19	0.19	2.6	0
557	6/17/2011	11:58	RR	22.3	7.4	-4.0	1.07	0.48	136.8	42.04526	-73.92516	0.94	0.18	0.18	1.55	0
558	6/21/2011	15:06	RR	23.9	8.3	-15.0	0.95	0.37	163.8	42.04635	-73.92512	0.62	0.05	0.06	2.1	0
559	6/17/2011	12:59	RR	22.5	7.4	-2.0	1.38	0.30	136.8	42.04688	-73.92505	0.25	0.03	0.07	0.7	0
560	6/21/2011	12:46	RR	24.1	4.1	-4.0	0.34	0.09	163.8	42.04741	-73.92508	0.47	0.04	0.07	3.5	90
562	6/21/2011	14:48	RR	24.0	7.4	-13.0	0.84	0.32	163.8	42.0428	-73.92541	0.37	0.03	0.04	7.5	100
564	6/28/2011	10:26	RR	23.0	7.2	17.0	1.31	0.16	210.4	42.04289	-73.92535	0.83	0.08	0.12	3.4	0
565	6/21/2011	13:11	RR	24.4	4.6	-5.0	0.39	0.12	163.8	42.04528	-73.92517	0.66	0.03	0.14	2.1	20
566	6/21/2011	15:25	RR	23.9	8.3	-16.0	1.06	0.35	163.8	42.041	-73.92549	0.94	0.06	0.06	5.2	100
568	6/21/2011	13:40	RR	24.4	5.8	-7.0	0.50	0.23	163.8	42.04389	-73.92529	0.64	0	0.09	1.95	85
570	6/28/2011	11:10	RR	23.2	7.3	14.0	1.35	0.05	210.4	42.04391	-73.92522	0.94	0.11	0.11	3.2	0
571	6/28/2011	11:22	RR	23.2	6.8	18.0	1.36	0.05	210.4	42.04448	-73.92521	0.84	0.07	0.11	1.4	0
572	6/28/2011	11:36	RR	23.2	6.8	18.0	1.36	0.00	210.4	42.04489	-73.92518	0.94	0.1	0.10	2	0
573	6/28/2011	11:46	RR	23.2	7.3	14.0	1.35	-0.06	210.4	42.04471	-73.9252	0.51	0.11	0.11	1.7	0
574	6/28/2011	9:50	RR	22.8	7.3	17.0	1.23	0.18	210.4	42.04119	-73.92547	1.23	0.03	0.06	8.9	100
575	6/21/2011	13:54	RR	24.2	6.4	1.0	0.57	0.30	163.8	42.04499	-73.92521	0.46	0.04	0.09	0.82	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	date	time	site	temp	DO	turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
576	6/28/2011	9:19	RR	22.8	7.2	16.0	1.12	0.24	210.4	42.04308	-73.92544	0.98	0.04	0.14	13.1	100
577	6/21/2011	15:44	RR	23.7	8.5	-10.0	1.17	0.35	163.8	42.0428	-73.92538	0.78	0.09	0.09	3.4	10
578	6/28/2011	12:01	RR	23.2	7.4	16.0	1.34	-0.04	210.4	42.04522	-73.92518	1.20	0.1	0.12	0.9	0
579	6/28/2011	9:37	RR	22.8	7.2	16.0	1.19	0.23	210.4	42.04221	-73.9254	1.08	0.06	0.08	8.3	100
580	6/21/2011	14:15	RR	24.0	6.6	-10.0	0.69	0.34	163.8	42.04752	-73.92511	0.50	0.01	0.07	4.6	100
583	6/28/2011	12:12	RR	23.2	7.5	14.0	1.31	-0.16	210.4	42.04681	-73.92504	0.62	0.05	0.05	2.3	0
585	6/28/2011	10:00	RR	22.9	7.2	24.0	1.25	0.12	210.4	42.04099	-73.92542	0.57	0.06	0.06	1.2	0
586	6/28/2011	10:11	RR	22.9	7.1	17.0	1.27	0.11	210.4	42.04185	-73.92539	1.13	0.04	0.06	5.5	0
595	6/21/2011	12:26	RR	24.0	4.8	-4.0	0.31	-0.09	163.8	42.0463	-73.9252	0.48	0.01	0.10	11.3	100
597	6/21/2011	14:33	RR	24.0	7.7	-15.0	0.76	0.23	163.8	42.04553	-73.9253	0.75	0.06	0.09	7.4	0
701	6/14/2011	12:07	CI	22.0	6.9	40.0	1.55	-0.03	119.4	42.02746	-73.92807	1.18	0.02	0.03	10	100
702	6/16/2011	13:01	CI	22.6	7.8	143.0	1.52	0.23	130.8	42.02803	-73.93026	0.82	0.02	0.02	2.9	0
703	6/16/2011	9:30	CI	21.8	7.0	127.0	0.4	0.33	130.8	42.02649	-73.92912	0.42	0.02	0.04	2.7	0
704	6/23/2011	9:57	CI	22.9	4.9	22.0	0.9	-0.08	177.4	42.028	-73.92749	0.51	0.01	0.04	2.4	0
704	6/14/2011	12:49	CI	21.9	7.1	32.0	1.51	-0.08	119.4	42.02793	-73.92778	0.67	0.04	0.04	4.5	0
705	6/16/2011	11:54	CI	22.4	7.7	141.0	1.24	0.17	130.8	42.02899	-73.92638	0.84	0.01	0.04	18.1	100
706	6/16/2011	9:50	CI	21.8	7.1	132.0	0.51	0.33	130.8	42.02867	-73.92638	0.28	0.01	0.04	15.2	100
707	6/16/2011	11:40	CI	22.2	7.6	151.0	1.20	0.43	130.8	42.02881	-73.92615	0.73	0.08	0.08	1.7	0
708	6/16/2011	12:45	CI	22.6	7.9	143.0	1.46	0.26	130.8	42.02829	-73.93008	0.39	0.07	0.07	1.45	0
709	6/23/2011	10:11	CI	22.9	4.8	26.0	0.87	0.01	177.4	42.0277	-73.92622	0.93	0.02	0.05	2.5	0
710	6/23/2011	10:29	CI	22.8	4.6	39.0	0.81	-0.20	177.4	42.02944	-73.92661	0.60	0.01	0.04	29.7	100
711	6/23/2011	12:30	CI	22.9	2.6	28.0	0.43	-0.19	177.4	42.0271	-73.92889	0.98	0.02	0.03	6.9	100
713	6/14/2011	12:33	CI	22.0	7.0	37.0	1.53	-0.05	119.4	42.02874	-73.92725	0.92	0.02	0.04	1.9	20
714	6/14/2011	13:21	CI	21.9	7.5	29.0	1.42	-0.17	119.4	42.02958	-73.9265	0.98	0.01	0.04	20	100
716	6/16/2011	13:24	CI	22.5	7.6	134.0	1.56	0.10	130.8	42.02726	-73.92814	0.89	0.02	0.04	5.85	0
719	6/16/2011	10:57	CI	22.2	7.7	153.0	0.89	0.42	130.8	42.02799	-73.92919	0.56	0.02	0.03	24.7	100
720	6/16/2011	10:31	CI	22.3	8.1	149.0	0.71	0.29	130.8	42.028	-73.9297	0.52	0.03	0.03	39.4	100
722	6/23/2011	11:47	CI	22.8	3.4	28.0	0.56	-0.23	177.4	42.0279	-73.92889	0.39	0.04	0.04	21.4	100
724	6/23/2011	12:11	CI	22.9	2.7	23.0	0.49	-0.18	177.4	42.0281	-73.92958	0.69	0.03	0.03	29.3	100
727	6/23/2011	10:53	CI	22.8	4.2	30.0	0.73	-0.20	177.4	42.02837	-73.92946	0.37	0.01	0.03	4.4	50

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	date	time	site	temp	DO	turb	wd	chg	dd	lat	long	depth	vel	maxvel	dfs	silt
728	6/23/2011	11:18	CI	22.8	4.0	23.0	0.66	-0.17	177.4	42.02824	-73.93056	0.43	0.02	0.02	1.6	0
729	6/29/2011	9:03	CI	22.8	4.6	10.0	0.73	0.20	217.4	42.02801	-73.93001	0.54	0.02	0.02	16.5	100
730	6/29/2011	12:05	CI	23.1	7.6	4.0	1.29	0.00	217.4	42.02836	-73.9002	0.61	0.03	0.03	2.8	0
732	6/29/2011	9:33	CI	22.7	7.4	10.0	0.85	0.24	217.4	42.02661	-73.92918	1.15	0.02	0.03	11.2	100
733	6/29/2011	9:45	CI	22.6	7.6	10.0	0.92	0.35	217.4	42.02817	-73.9295	0.60	0.03	0.03	19.1	100
734	6/29/2011	9:59	CI	22.6	7.6	11.0	0.99	0.30	217.4	42.0282	-73.92623	0.81	0.08	0.08	2.5	20
735	6/29/2011	11:15	CI	23.2	8.0	10.0	1.25	0.20	217.4	42.0272	-73.9283	0.88	0.06	0.06	11.7	100
736	6/29/2011	10:10	CI	22.6	7.7	11.0	1.04	0.27	217.4	42.0281	-73.92622	0.60	0.07	0.07	1.4	0
737	6/29/2011	11:40	CI	23.3	8.0	9.0	1.29	0.09	217.4	42.02712	-73.92831	0.82	0.04	0.04	6.4	100
738	6/29/2011	10:19	CI	22.7	7.7	11.0	1.06	0.13	217.4	42.02811	-73.9263	1.06	0.01	0.05	13.7	100
739	6/29/2011	11:26	CI	23.2	8.1	9.0	1.27	0.11	217.4	42.02819	-73.92941	0.94	0.02	0.03	16.2	100
741	6/29/2011	12:17	CI	23.0	7.9	5.0	1.28	-0.05	217.4	42.0279	-73.92857	0.99	0.01	0.03	8.2	90
745	6/23/2011	11:34	CI	22.8	3.8	25.0	0.61	-0.19	177.4	42.02723	-73.92815	0.41	0.04	0.04	2.4	50
746	6/16/2011	14:12	CI	22.8	7.7	125.0	1.54	-0.03	130.8	42.02704	-73.92836	0.92	0.04	0.04	2.45	0
747	6/29/2011	12:29	CI	23.1	7.9	7.0	1.26	-0.10	217.4	42.02697	-73.92847	0.47	0.03	0.04	1.1	20
749	6/23/2011	12:54	CI	22.9	2.2	28.0	0.40	-0.08	177.4	42.0279	-73.92629	0.81	0.05	0.05	9	100

Table A.4. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
101	10	0	0	0	1.1	0	0	0	0	9	0	1	0	0	0	0	0
104	20	20	20	20	3	5	0	5	0	17	0	1	0	0	0	0	0
120	0	10	50	40	4.3	0	0	0	0	0	0	0	0	0	0	0	0
123	20	40	0	0	2	0	0	0	0	11	0	0	0	0	0	0	0
124	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
125	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
126	40	50	10	0	2.7	0	0	0	0	4	0	0	0	0	0	0	0
127	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
130	0	40	10	0	2.1	0	0	0	0	2	0	0	0	0	0	0	0
128	10	70	10	0	2.8	0	0	0	0	19	0	0	0	0	0	0	0
129	0	30	15	10	2.45	0	0	0	0	1	1	0	0	0	0	0	0
139	10	10	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0
140	0	20	70	10	3.9	0	0	0	0	0	0	0	0	0	0	0	0
143	35	35	15	15	3.1	0	0	0	0	0	13	0	0	0	0	0	0
144	20	40	20	0	2.6	0	0	0	0	2	2	0	0	0	1	0	0
145	30	40	0	0	2.1	0	0	0	0	1	0	1	0	0	0	0	0
148	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
151	30	50	10	10	3	0	0	0	0	1	1	0	0	0	0	0	0
153	0	20	30	50	4.3	0	0	0	0	0	5	0	0	0	0	1	0
155	30	50	0	20	3.1	0	0	0	0	2	0	0	0	0	0	0	0
156	30	40	0	0	2.1	0	0	0	0	41	0	0	0	0	0	0	0
159	0	0	0	35	2.4	0	0	0	0	0	4	0	0	0	1	0	0
160	10	40	50	0	3.4	0	0	0	0	10	3	0	0	0	1	1	0
162	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0
164	0	40	20	40	4	0	0	0	0	0	2	0	0	0	0	0	0
168	0	0	0	0	1	15	0	15	0	0	0	0	0	0	0	0	0
169	10	80	10	0	3	0	0	0	0	2	0	0	0	0	0	0	0
171	35	50	15	0	2.8	0	0	0	0	0	1	0	0	1	0	0	0
172	0	0	0	0	1	6	0	6	0	0	0	1	0	0	2	0	0
173	0	0	0	0	1	0	0	0	0	22	0	1	0	0	1	0	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
175	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
177	5	60	20	15	3.45	0	0	0	0	22	0	1	0	0	0	0	0
178	0	0	0	0	1	7	1	5	1	4	0	1	0	0	2	0	0
179	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0
181	0	0	0	0	1	1	0	0	1	0	2	0	0	0	1	0	0
185	0	80	10	10	3.3	0	0	0	0	0	0	0	0	0	0	0	0
190	50	25	5	0	2.2	0	0	0	0	2	315	0	0	0	0	2	0
191	50	20	0	0	1.9	1	1	0	0	0	4	0	0	0	0	1	0
192	0	0	0	0	1	20	0	20	0	0	9	0	0	1	0	0	0
196	0	0	0	0	1	21	1	20	0	0	0	0	0	0	0	1	0
197	0	0	0	0	1	1	1	0	0	0	179	1	0	0	3	0	0
198	0	0	0	0	1	0	0	0	0	28	0	0	0	0	0	0	0
199	0	0	0	0	1	5	5	0	0	1	0	0	0	0	0	0	0
200	0	0	0	0	1	10	10	0	0	0	1	0	0	0	0	1	0
201	0	0	0	0	1	1	1	0	0	2	1	0	0	0	0	6	0
203	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0
204	0	5	5	0	1.25	7	0	0	0	2	3	0	0	0	0	2	0
205	0	0	0	0	1	15	0	15	0	12	4	2	0	0	0	0	0
206	0	0	0	0	1	10	0	10	0	2	0	3	0	0	1	0	0
207	0	0	0	0	1	5	5	0	0	19	0	4	0	0	0	0	0
208	0	10	50	40	4.3	0	0	0	0	0	0	0	0	0	0	0	0
209	10	10	20	10	2.3	5	5	0	0	0	0	0	0	1	0	0	0
213	10	0	10	0	1.4	1	0	0	0	0	25	0	0	1	0	1	0
215	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
216	0	0	0	0	1	25	25	0	0	0	10	0	0	0	2	0	0
217	0	0	0	0	1	3	1	0	2	141	0	3	1	0	1	0	1
245	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0
252	0	0	0	0	1	15	15	0	0	0	0	0	0	0	0	0	0
269	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
271	0	0	0	0	1	0	0	0	0	24	1	0	0	0	0	0	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
311	0	70	30	0	3.3	0	0	0	0	96	0	0	0	0	0	0	0
312	0	0	30	70	4.7	0	0	0	0	0	0	0	0	0	0	0	0
314	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
315	0	30	30	40	4.1	0	0	0	0	0	0	0	0	0	0	0	0
316	0	0	0	0	1	1	1	0	0	13	0	0	0	0	0	0	0
318	10	60	20	0	2.9	1	0	0	1	1	1	0	0	0	0	0	0
320	0	0	0	0	1	5	0	0	5	2	0	0	0	0	0	0	0
321	0	40	50	10	3.7	0	0	0	0	0	5	0	0	0	0	0	0
322	0	20	80	0	3.8	0	0	0	0	360	0	1	0	0	3	0	0
323	0	50	50	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0
325	0	0	0	0	1	5	0	0	5	10	0	0	0	0	0	0	0
328	5	70	5	20	3.4	0	0	0	0	0	0	0	0	0	0	0	0
333	0	0	20	80	4.8	0	0	0	0	0	0	0	0	0	0	0	0
342	10	30	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0
343	5	5	0	0	1.15	0	0	0	0	0	0	0	0	0	0	0	0
345	0	70	10	20	3.5	0	0	0	0	0	0	0	0	0	0	0	0
346	30	10	0	0	1.5	0	0	0	0	5	0	0	0	0	0	0	0
348	0	70	10	0	2.7	1	1	0	0	10	0	0	0	0	0	0	0
349	10	60	10	0	2.6	0	0	0	0	0	0	0	0	0	0	0	0
350	0	20	60	20	4	0	0	0	0	4	0	0	0	0	0	0	0
351	0	40	40	20	3.8	0	0	0	0	0	14	0	0	0	0	0	0
352	30	10	0	0	1.5	5	0	0	0	2	0	1	0	0	0	0	0
354	0	50	40	10	3.6	1	1	0	0	0	0	0	0	0	0	0	0
368	10	60	30	0	3.2	1	1	0	0	11	0	0	0	0	0	0	0
369	20	10	40	20	3.4	0	0	0	0	0	0	0	0	0	0	0	0
371	0	0	0	0	1	5	2	0	3	0	0	0	0	0	0	0	0
374	0	60	20	20	3.6	0	0	0	0	0	0	0	0	0	0	0	0
375	0	30	20	50	4.2	0	0	0	0	0	0	0	0	0	0	0	0
377	0	15	75	10	3.95	0	0	0	0	0	0	1	0	0	0	0	0
378	0	40	20	20	3.2	1	1	0	0	4	0	1	0	0	0	0	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
379	0	0	0	0	1	5	0	0	0	25	0	2	0	0	4	0	0
387	0	0	0	0	1	5	0	0	5	0	1	0	0	0	2	0	0
389	20	30	20	0	2.4	1	1	0	0	0	20	0	0	0	0	0	0
400	0	50	30	20	3.7	0	0	0	0	0	0	0	0	0	0	1	0
401	0	0	0	0	1	5	0	0	5	0	0	0	0	0	2	0	0
402	10	30	30	30	3.8	0	0	0	0	4	0	0	0	0	0	0	0
403	10	90	0	0	2.9	0	0	0	0	1	0	0	0	0	0	0	0
404	50	20	0	0	1.9	0	0	0	0	21	0	0	0	0	0	0	0
405	0	60	20	20	3.6	0	0	0	0	0	0	1	0	0	0	0	0
406	0	80	20	0	3.2	0	0	0	0	13	0	0	0	0	0	0	0
407	30	70	0	0	2.7	0	0	0	0	2	0	0	0	0	0	0	0
409	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
410	0	10	0	90	4.8	0	0	0	0	0	0	0	0	0	0	0	0
413	0	80	20	0	3.2	0	0	0	0	1	1	0	0	0	0	0	0
417	30	50	0	0	2.3	0	0	0	0	5	0	0	0	0	0	0	0
420	60	20	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0
421	40	20	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0
422	50	25	15	0	2.45	0	0	0	0	17	0	0	0	0	0	0	0
423	0	30	50	20	3.9	0	0	0	0	0	0	0	0	0	0	0	0
424	0	0	0	0	1	11	1	0	10	0	0	0	0	0	8	0	1
426	40	30	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
427	0	30	70	0	3.7	0	0	0	0	1	0	0	0	0	0	0	0
428	0	40	50	10	3.7	0	0	0	0	1	0	0	0	0	0	0	0
429	20	80	0	0	2.8	0	0	0	0	2	0	0	0	0	0	0	0
430	25	40	10	25	3.35	0	0	0	0	1	0	0	0	0	0	0	0
431	20	30	20	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0
433	20	70	0	0	2.6	0	0	0	0	0	0	0	0	0	0	0	0
436	0	90	10	0	3.1	0	0	0	0	8	0	0	0	0	0	0	0
437	30	40	0	0	2.1	25	0	0	25	1	0	0	0	0	0	0	0
440	0	100	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
441	15	75	10	0	2.95	1	0	0	1	0	0	0	0	0	0	0	0
442	0	0	0	0	1	25	0	0	25	2	0	1	0	0	0	0	1
443	30	30	0	0	1.9	3	0	0	3	0	0	0	0	0	0	0	1
444	40	50	0	10	2.8	0	0	0	0	2	0	0	0	0	0	0	0
446	50	50	0	0	2.5	0	0	0	0	14	0	0	0	0	0	0	0
448	0	0	0	0	1	0	0	0	0	0	9	0	0	0	1	0	1
449	20	30	20	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0
551	40	10	0	0	1.6	0	0	0	0	0	0	0	5	0	0	0	0
552	0	20	80	0	3.8	0	0	0	0	0	0	0	0	0	0	0	0
553	15	10	75	0	3.6	0	0	0	0	0	16	0	0	0	0	0	0
554	0	10	20	70	4.6	0	0	0	0	0	0	0	0	0	0	0	0
555	0	25	60	15	3.9	0	0	0	0	0	0	0	0	0	0	0	0
556	0	60	30	10	3.5	0	0	0	0	0	0	0	0	0	0	0	0
557	0	75	15	10	3.35	0	0	0	0	0	0	0	0	0	0	0	0
558	0	40	60	0	3.6	0	0	0	0	0	0	0	0	0	0	0	0
559	0	50	50	0	3.5	0	0	0	0	0	2	0	0	0	0	0	0
560	0	0	0	10	1.4	5	0	0	5	0	0	0	0	0	10	1	0
562	0	0	0	0	1	5	0	0	5	0	0	0	0	0	0	0	0
564	0	0	50	50	4.5	0	0	0	0	0	0	0	0	0	0	0	0
565	0	70	10	0	2.7	1	1	0	0	1	0	0	0	0	0	0	0
566	0	0	0	0	1	1	1	0	0	2	0	1	0	0	0	0	0
568	10	5	0	0	1.2	1	0	0	1	0	0	1	0	0	0	0	0
570	0	0	30	70	4.7	0	0	0	0	0	0	0	0	0	0	0	0
571	0	0	0	100	5	0	0	0	0	0	0	0	0	0	0	0	0
572	0	10	50	40	4.3	0	0	0	0	0	0	0	0	0	0	0	0
573	0	0	20	80	4.8	0	0	0	0	0	0	0	0	0	0	0	0
574	0	0	0	0	1	26	1	0	25	0	0	0	0	0	0	0	0
575	0	50	50	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0
576	0	0	0	0	1	16	1	5	10	8	0	0	0	0	1	0	1
577	10	10	70	0	3.4	0	0	0	0	0	0	0	0	0	0	0	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
578	0	0	0	100	5	0	0	0	0	0	0	0	0	0	0	0	0
579	0	0	0	0	1	26	1	0	25	0	0	0	0	0	0	0	0
580	0	0	0	0	1	15	0	0	15	0	0	0	0	0	3	0	0
583	0	50	40	10	3.6	0	0	0	0	3	0	0	0	0	0	0	0
585	0	30	30	40	4.1	5	5	0	0	0	0	0	0	0	0	1	0
586	0	80	20	0	3.2	1	1	0	0	0	0	0	0	0	0	0	0
595	0	0	0	0	1	25	0	0	25	0	0	1	0	0	4	0	1
597	10	80	10	0	3	0	0	0	0	0	0	0	0	0	0	0	0
701	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
702	0	80	20	0	3.2	0	0	0	0	7	0	0	0	0	0	0	0
703	0	0	0	100	5	0	0	0	0	0	1	0	0	0	0	0	0
704	100	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
704	100	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
705	0	0	0	0	1	75	25	50	0	0	0	1	0	0	0	0	0
706	0	0	0	0	1	70	70	0	0	0	2	0	0	0	0	4	0
707	0	0	0	100	5	1	1	0	0	0	0	0	0	0	0	0	0
708	0	30	30	40	4.1	0	0	0	0	0	2	1	0	0	0	0	0
709	0	0	50	50	4.5	0	0	0	0	0	0	0	0	0	0	0	0
710	0	0	0	0	1	31	0	30	1	0	0	0	0	0	0	0	0
711	0	0	0	0	1	20	0	0	20	0	0	3	0	0	0	0	0
713	30	50	0	0	2.3	0	0	0	0	0	0	3	0	0	0	1	0
714	0	0	0	0	1	25	0	25	0	0	0	0	0	4	0	0	0
716	0	100	0	0	3	0	0	0	0	99	0	0	0	0	0	0	0
719	0	0	0	0	1	6	1	5	0	0	0	6	0	0	0	0	0
720	0	0	0	0	1	10	5	5	0	0	0	6	0	0	0	0	2
722	0	0	0	0	1	5	0	5	0	118	0	0	0	0	0	1	0
724	0	0	0	0	1	6	1	5	0	1	0	0	0	0	0	0	1
727	50	0	0	0	1.5	15	0	0	0	0	7	0	0	3	0	1	0
728	0	30	70	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0
729	0	0	0	0	1	55	50	5	0	0	1	2	0	0	0	0	0

Table A.4 continued. Habitat variables and number of larval and adult fishes collected for each throw trap sample.

trapID	sand	gravel	cobble	boulder	subcode	vegcover	TRNA	NULU	VAAM	clu	cyp	mor	cen	fun	per	funmat	permat
730	20	50	30	0	3.1	5	0	0	0	0	0	0	0	0	0	0	0
732	0	0	0	0	1	51	1	0	50	0	0	0	0	0	0	0	0
733	0	0	0	0	1	5	0	5	0	0	0	0	0	0	0	0	0
734	0	20	20	40	3.6	50	50	0	0	0	1	0	0	0	0	0	0
735	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
736	0	10	30	60	4.5	1	1	0	0	0	0	0	0	0	0	0	0
737	0	0	0	0	1	0	0	0	0	8	0	0	0	0	0	0	0
738	0	0	0	0	1	80	80	0	0	0	4	0	0	3	0	0	0
739	0	0	0	0	1	10	0	10	0	0	0	0	0	0	0	0	0
741	0	10	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0
745	20	30	0	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0
746	30	50	20	0	2.9	0	0	0	0	1	1	0	0	0	0	0	0
747	50	30	0	0	2.1	0	0	0	0	0	0	0	0	0	0	0	0
749	0	0	0	0	1	50	50	0	0	0	0	4	0	1	0	0	0

Table A.5. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
101	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0
101	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0
101	12.5	0	0	0	1	0	0	0	0	0	0	0	0	0
101	12.7	0	0	0	0	0	0	0	0	0	0	0	0	0
101	13.4	0	0	0	0	0	0	0	0	0	0	0	0	0
101	13.9	0	0	0	0	0	0	0	0	0	0	0	0	0
101	14	0	0	0	1	0	0	0	0	0	0	0	0	0
101	14.2	1	2	0	0	0	0	0	0	0	0	0	0	0
101	14.4	0	0	0	0	0	0	0	0	0	0	0	0	0
104	5.1	0	0	0	1	0	0	0	0	0	0	0	0	0
104	9.8	0	0	0	0	0	0	0	0	0	0	0	0	0
104	11.9	0	0	0	3	0	0	0	0	0	8	0	0	10
104	10	0	0	0	2	3	0	0	0	0	3	0	0	3
104	7.7	0	0	0	0	0	0	0	0	0	0	0	0	1
104	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
104	5.7	0	0	0	0	0	0	0	0	0	1	0	0	0
104	6.7	1	0	0	0	0	0	0	0	0	0	0	0	0
104	7.2	0	0	0	0	0	0	0	0	0	2	0	0	0
104	7.1	0	0	0	0	0	0	0	0	0	2	0	0	0
104	7.4	0	0	0	0	0	0	0	0	0	0	0	0	0
104	6.1	0	0	0	0	0	0	0	0	0	0	0	0	2
104	7	0	1	0	0	0	1	0	0	0	1	0	0	0
104	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
104	5.3	0	0	0	0	0	0	0	0	0	0	0	0	4
104	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
104	5.7	0	0	0	0	0	0	0	0	0	1	1	0	0
123	5	0	0	0	0	0	0	0	0	0	0	0	0	0
123	9.4	0	0	0	1	0	0	0	0	0	0	0	0	0
123	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
123	4	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
123	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0
123	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
123	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0
123	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
123	4.3	0	0	0	0	0	0	0	0	0	0	0	0	1
123	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0
123	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
126	5	0	0	0	0	0	0	0	0	0	0	0	0	0
126	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0
126	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
126	4.8	0	0	0	0	0	0	0	0	0	0	0	1	0
127	10.6	0	2	0	0	0	0	0	0	0	4	0	0	0
128	7.2	0	0	1	0	0	0	0	0	0	0	0	0	0
128	11.9	0	1	0	0	0	0	0	0	0	0	0	0	0
128	9.9	0	0	0	0	0	0	0	0	0	0	0	0	0
128	8.2	0	0	0	0	0	0	0	0	0	0	0	0	0
128	13.6	0	0	0	0	0	0	0	0	0	0	0	0	0
128	11.8	0	0	0	0	0	0	0	0	0	1	0	0	1
128	9.8	0	1	0	0	0	0	0	0	0	2	0	0	0
128	15.5	0	0	0	0	0	0	0	0	0	0	0	0	0
128	15.3	0	0	0	0	0	0	0	0	0	0	0	0	0
128	7.8	0	0	0	0	0	0	0	0	0	3	0	0	0
128	7.7	0	0	0	0	0	0	0	0	0	0	0	0	0
128	8.2	0	1	0	0	0	0	1	0	0	0	0	0	0
128	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0
128	7.4	1	0	0	0	0	0	0	0	0	0	1	0	0
128	5.3	0	0	0	0	0	0	0	0	0	0	3	0	0
128	7.4	0	0	0	1	0	0	0	0	0	0	3	0	0
128	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
128	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
128	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
129	10.2	0	0	0	0	0	0	0	0	0	0	0	0	0
130	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0
130	4.6	0	0	0	0	0	0	0	0	0	0	0	1	0
144	7.6	0	1	0	1	0	0	0	0	0	0	0	0	0
144	11.2	0	0	0	0	0	0	0	0	0	0	0	0	0
145	12.6	0	0	0	2	0	0	0	0	0	1	0	0	0
151	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0
155	7.9	0	0	0	0	0	0	0	0	0	0	0	0	1
155	11.9	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.6	0	0	0	0	0	0	0	0	0	1	0	0	0
156	8.4	0	0	0	0	0	0	0	0	0	0	0	0	1
156	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
156	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0
156	9.9	0	0	0	0	0	0	0	0	0	0	0	0	2
156	5	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
156	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
156	4.9	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.8	0	0	0	0	0	0	0	0	0	0	0	0	2
156	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.5	0	0	0	0	0	0	0	0	0	1	0	0	0
156	5.2	0	0	0	0	0	0	0	0	0	1	0	0	0
156	6.9	0	0	0	0	0	0	0	0	0	1	0	0	0
156	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0
156	10.1	0	0	0	0	0	0	0	0	0	1	0	0	0
156	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
156	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0
156	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
156	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
160	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0
160	6.4	0	0	0	0	0	0	0	0	0	0	0	0	0
160	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0
160	6.6	0	0	0	0	0	0	0	0	0	2	0	0	0
160	4.9	0	0	0	0	0	0	0	0	0	0	0	0	1
160	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
160	5.9	0	0	0	0	0	0	0	0	0	0	0	0	2
160	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
160	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
160	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
169	5.8	0	0	0	1	0	0	0	0	0	0	0	0	5
169	13.9	0	0	0	0	0	0	0	0	0	4	1	0	3
173	11.3	0	0	0	1	0	0	0	0	0	7	0	0	0
173	11.9	0	0	0	1	0	0	0	0	0	3	1	0	0
173	10.9	0	2	0	0	0	0	0	0	0	9	0	0	0
173	11.2	0	1	0	0	0	0	0	0	0	2	0	0	0
173	9.5	0	2	0	0	0	0	0	0	0	1	0	0	0
173	10	0	0	0	0	0	0	0	0	0	0	0	0	0
173	6.7	0	0	0	2	0	0	0	0	0	0	1	0	0
173	8	0	0	0	0	0	0	0	0	0	0	0	0	0
173	6.9	0	0	0	1	0	0	0	0	0	0	0	0	0
173	14.5	0	0	0	0	0	0	0	0	0	1	0	0	0
173	9.3	0	0	0	0	0	0	0	0	0	0	0	0	8
173	10.9	0	0	0	1	0	1	0	0	0	0	0	0	0
173	7.7	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
173	8.4	0	0	0	0	0	0	0	0	0	0	0	0	0
173	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0
173	9.7	0	4	0	0	0	0	0	0	0	1	0	0	0
173	11.9	0	0	0	1	0	0	0	0	0	5	0	0	0
173	7	0	0	0	0	0	0	0	0	0	0	0	0	0
173	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0
173	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
173	6.9	0	0	0	0	0	0	0	0	0	0	0	0	0
173	7.3	0	0	0	0	0	0	0	0	0	0	0	0	1
175	7.4	0	0	0	0	0	1	0	0	0	0	0	0	0
177	13.6	0	0	0	0	0	0	0	0	0	0	0	0	0
177	11.3	0	0	0	0	0	0	0	0	0	0	0	0	0
177	11.7	0	0	0	0	0	0	0	0	0	0	0	0	0
177	11.3	0	0	0	0	0	0	0	0	0	0	0	0	0
177	11.4	0	0	0	1	0	0	0	0	0	1	0	0	2
177	11.5	0	0	0	0	0	0	0	0	0	0	0	0	0
177	11.6	0	0	0	0	0	0	0	0	0	0	0	0	0
177	8.1	0	0	0	0	0	0	0	0	0	0	0	0	0
177	10.8	0	0	0	0	0	0	0	0	0	0	0	0	0
177	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0
177	10.8	0	0	0	2	1	0	0	0	0	0	0	0	0
177	10	0	0	0	0	0	0	0	0	0	0	0	0	0
177	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0
177	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
177	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0
177	8.2	0	0	0	0	0	0	0	0	0	0	0	0	0
177	8.3	0	0	0	0	0	1	0	0	0	0	0	0	0
177	8.2	0	0	0	0	0	0	0	0	0	0	0	0	0
177	7.4	0	0	0	0	0	0	0	0	0	0	0	0	0
177	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
177	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
177	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
178	6.6	0	0	0	1	0	0	0	0	0	0	0	0	0
178	9.3	0	0	0	1	0	0	0	0	0	1	0	0	0
178	9.6	1	0	0	1	0	0	0	0	0	1	0	0	0
178	11.9	1	0	0	2	0	0	0	0	0	0	0	0	0
179	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0
179	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0
179	7.4	0	0	0	0	0	0	0	0	0	0	0	0	0
179	11.3	0	0	0	0	0	0	0	0	0	0	0	0	0
190	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0
190	7.8	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.5	0	0	0	0	0	0	0	0	0	0	2	0	0
198	12.3	0	0	0	1	0	1	0	0	0	0	2	0	0
198	10.5	0	0	0	0	0	0	0	0	0	0	2	0	0
198	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
198	5.9	0	0	0	0	0	0	0	0	0	1	0	0	0
198	6.9	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.4	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.4	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6	0	0	0	0	0	0	0	0	0	0	0	0	0
198	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
198	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0
198	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0
198	5.6	0	0	0	0	0	0	0	0	0	0	1	0	0
198	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0
198	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
198	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0
198	6.4	0	0	0	0	0	1	0	0	0	0	2	0	0
198	5.4	0	0	0	0	0	1	0	0	0	0	0	0	0
198	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0
198	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
199	10	0	0	0	0	0	0	0	0	0	1	0	2	0
201	6.4	0	0	0	0	0	0	0	0	0	0	0	0	0
201	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0
203	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0
204	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
204	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0
205	8.2	0	0	0	0	0	0	0	0	0	0	0	0	1
205	8.7	0	0	0	1	0	0	0	0	0	0	0	0	0
205	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
205	7.2	0	1	0	0	0	0	0	0	0	0	0	0	0
205	5	0	0	0	0	0	0	0	0	0	0	0	0	0
205	6.9	0	0	0	0	0	0	0	0	0	0	0	0	0
205	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0
205	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
205	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
205	7	0	0	0	0	0	1	0	0	0	0	0	0	0
205	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0
205	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0
206	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
206	7.4	0	0	0	0	0	0	0	0	0	0	0	0	0
207	8.5	0	0	0	2	0	0	0	0	0	0	0	0	0
207	10	0	0	0	1	0	0	0	0	0	0	0	0	0
207	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
207	7.6	0	0	0	2	0	0	0	0	0	0	0	0	1
207	8.9	0	0	0	1	0	0	0	0	0	2	0	0	0
207	5.9	0	0	0	0	0	0	0	0	0	1	0	0	0
207	6.1	0	0	0	0	0	0	0	0	0	2	0	0	0
207	8.3	0	1	0	2	0	0	0	0	0	1	0	0	0
207	6.8	0	1	0	0	0	0	0	0	0	0	0	0	0
207	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
207	6.6	0	0	0	0	0	0	0	0	0	2	0	0	0
207	6.6	0	0	0	0	0	0	0	0	0	1	0	0	0
207	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
207	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
207	7.2	0	0	0	1	0	0	0	0	0	0	0	0	0
207	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0
207	6.4	0	0	0	0	0	0	0	0	0	1	0	0	0
207	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0
207	11.2	0	0	0	1	0	0	0	0	0	0	0	0	0
217	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7.2	0	0	0	0	0	0	0	0	0	0	1	0	0
217	7.8	0	0	0	0	0	0	0	0	0	0	0	0	3
217	9.9	0	0	0	0	0	0	0	0	0	0	0	0	0
217	9.5	0	0	0	0	0	0	0	0	0	0	0	0	0
217	6.1	0	0	0	0	0	0	0	0	0	0	0	0	1
217	8.1	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7.4	0	0	0	0	0	1	0	0	0	0	0	0	0
217	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7.8	0	0	0	0	0	0	0	0	0	0	1	0	0
217	9.9	0	0	0	0	0	0	0	0	0	0	1	0	0
217	7.4	0	0	0	0	0	0	0	0	0	0	0	0	0
217	8.1	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7.7	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
217	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0
217	8.5	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0
217	8.4	0	0	0	0	0	0	0	0	0	0	0	0	0
217	8	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7	0	0	0	0	0	0	0	0	0	0	0	0	0
217	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
217	7.9	0	0	0	0	0	0	0	0	0	0	0	0	0
217	8.4	0	0	0	0	0	0	0	0	0	0	0	0	0
217	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0
271	10	0	0	0	0	0	0	0	0	0	0	0	0	0
271	7.9	0	0	0	2	0	0	0	0	0	0	0	0	0
271	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
271	6.2	0	0	0	1	0	0	0	0	0	1	0	0	0
271	8.3	0	0	0	1	0	0	0	0	0	0	0	0	3
271	6	0	0	0	0	0	0	0	0	0	0	0	0	0
271	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0
271	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
271	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
271	6	0	0	0	0	0	0	0	0	0	0	0	0	0
271	5.3	0	0	0	0	0	0	0	0	0	0	0	1	0
271	5.9	0	0	0	0	0	0	0	0	0	0	0	1	0
271	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0
271	4.7	0	0	0	0	0	0	0	0	0	3	0	0	0
271	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
271	4.8	0	0	0	0	0	0	0	0	0	0	0	1	0
271	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
271	6	0	0	0	0	0	0	0	0	0	1	0	1	0
271	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
271	5.8	0	0	0	0	0	0	0	0	0	0	1	0	0
271	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
271	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0
271	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
271	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
311	3.9	0	0	0	0	0	0	0	0	0	0	0	0	0
311	7	0	0	0	0	0	0	0	0	0	0	0	0	0
311	8.1	0	0	0	0	0	0	0	0	0	0	0	0	0
311	11.2	0	0	0	0	0	0	0	0	0	0	0	0	0
311	9	0	0	0	0	0	0	0	0	0	0	0	0	0
311	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
311	4.9	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
311	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0
311	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5.2	0	0	0	0	0	0	0	0	0	0	0	1	0
311	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
311	5	0	0	0	0	0	1	0	0	0	0	2	0	0
311	3	0	0	0	0	0	0	0	0	0	0	0	0	0
311	4.5	0	0	0	0	0	0	0	0	0	0	0	0	3
311	5	0	0	0	0	0	0	0	0	0	0	2	0	0
311	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0
311	4.3	0	0	0	0	0	0	0	0	0	0	0	0	0
311	4.2	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.2	0	0	0	1	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
316	11	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.4	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.4	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.7	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.4	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.8	0	3	0	0	0	0	0	0	0	0	0	0	0
316	11.9	2	1	0	0	0	0	0	0	0	4	0	0	0
316	12.1	0	0	0	0	0	0	0	0	0	0	0	0	0
316	11.9	0	0	0	0	0	0	0	0	0	0	0	0	0
316	12.6	0	0	0	1	0	0	1	0	0	0	0	0	0
316	13.1	0	1	0	0	0	0	0	0	0	2	0	0	0
316	13.3	0	0	0	0	0	0	0	0	0	1	0	0	0
318	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
320	6	0	0	0	0	0	0	0	0	0	0	0	0	0
320	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
322	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0
322	11.2	0	0	0	0	0	0	0	0	0	0	0	0	0
322	11.3	0	0	0	0	0	0	0	2	0	3	0	0	0
322	12	0	0	0	0	0	0	0	0	0	0	0	0	0
322	12.8	0	0	0	0	0	0	0	0	0	0	0	0	0
322	13.2	0	0	0	0	0	0	0	5	0	0	0	0	0
322	13.6	0	0	0	0	0	0	0	0	0	0	0	0	0
322	13.7	0	0	0	0	0	0	0	0	0	0	0	0	0
322	13.8	1	1	0	0	0	0	0	0	0	0	0	0	2
322	14.4	0	0	0	0	0	0	0	0	0	0	0	0	0
322	15.1	0	0	0	0	0	1	0	0	0	0	0	0	8
322	15.2	0	0	0	0	0	1	0	0	0	0	0	0	2
322	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
322	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
322	15.4	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
322	15.4	0	0	0	0	0	1	0	0	0	0	0	0	0
322	15.4	0	0	0	0	0	0	0	0	0	0	0	0	0
322	15.5	0	0	0	0	0	0	0	0	0	0	0	0	0
322	15.9	0	0	0	0	0	0	0	0	0	0	0	0	0
322	16.2	0	0	0	0	0	0	0	0	0	0	0	0	6
322	16.5	0	0	0	0	0	6	0	10	0	0	0	0	0
322	16.7	0	0	0	0	0	0	0	0	0	0	0	0	0
322	16.8	0	0	0	0	0	0	0	0	0	0	0	0	0
322	17.3	0	0	0	0	0	0	0	0	0	0	0	0	0
322	17.6	0	0	0	0	0	0	0	0	0	0	0	0	0
322	18.1	0	0	0	0	0	0	0	0	0	0	0	0	0
325	7.1	1	0	0	1	0	0	0	0	0	0	0	0	0
325	7.8	0	0	0	0	0	0	0	0	0	1	0	0	0
325	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0
325	11.8	0	0	0	1	0	0	0	0	0	0	0	0	0
325	14.1	1	0	0	2	0	0	0	0	0	1	0	0	0
325	14.7	0	0	0	1	0	0	0	0	0	0	0	0	0
325	14.9	0	1	1	1	0	0	0	0	0	0	0	0	0
325	15.7	0	0	1	3	0	0	0	0	0	1	0	0	0
325	17.2	0	1	0	0	0	0	0	0	0	1	0	0	0
325	20.9	0	1	2	3	0	1	0	0	0	1	0	1	0
344	12.1	2	0	0	0	0	0	0	0	0	10	1	13	0
346	5.3	0	0	0	0	1	0	0	0	0	0	0	0	0
346	6.9	0	0	0	0	0	0	0	0	0	0	0	0	0
346	9.9	1	0	0	0	0	0	0	0	0	0	0	0	0
346	6.3	0	0	0	1	0	0	0	0	0	0	0	0	0
346	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
348	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
348	7	0	0	0	0	0	0	0	0	0	0	0	0	0
348	10	0	0	0	1	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
348	7.2	0	0	0	0	0	0	0	0	0	0	0	0	1
348	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0
348	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
348	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0
348	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0
348	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0
348	5.3	1	0	0	0	0	0	0	0	0	0	0	0	0
350	8	0	0	0	0	0	0	0	0	0	1	1	0	0
350	9.9	0	1	0	1	0	0	0	0	0	0	0	0	0
350	11.6	0	0	0	1	0	0	0	0	0	2	0	0	0
350	12.1	0	0	0	0	0	0	0	0	0	0	0	0	0
352	12.1	0	0	0	0	0	0	0	0	0	0	0	0	0
352	8.2	0	0	1	2	0	0	0	0	0	0	0	0	0
368	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0
368	8	0	0	0	3	0	0	0	0	0	0	0	0	0
368	9.6	0	0	0	1	0	0	0	0	0	0	0	0	0
368	10	0	0	0	3	0	0	0	0	0	0	0	0	0
368	9.7	0	1	0	4	0	0	0	0	0	1	0	0	0
368	10	0	0	0	5	0	0	0	0	0	2	0	0	0
368	10.7	0	0	1	5	0	0	0	0	0	0	0	0	0
368	10.7	1	0	0	8	0	0	0	0	0	0	0	0	0
368	11.2	0	2	0	2	0	0	0	0	0	0	0	0	0
368	11.9	1	0	0	3	0	0	0	0	0	0	0	0	0
368	13.3	0	1	0	4	0	0	0	0	0	0	0	0	0
378	4.9	0	0	0	0	0	0	0	0	0	0	0	0	0
378	8.1	0	0	0	1	0	0	0	0	0	2	0	0	0
378	10	0	0	0	1	0	0	0	0	0	6	0	0	0
378	10.3	0	0	0	2	0	0	0	0	0	1	0	0	0
379	7.1	0	0	0	0	0	0	0	0	0	0	2	0	0
379	6.9	0	0	0	0	0	0	0	0	0	0	0	0	1

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
379	5.5	0	0	0	0	0	0	0	0	0	0	1	0	0
379	6.9	0	0	0	0	0	0	0	0	0	0	0	0	1
379	8.1	0	0	0	0	0	0	0	0	0	0	0	0	0
379	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0
379	8.9	0	0	0	0	0	0	0	0	0	0	4	0	0
379	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
379	6.8	0	0	0	0	0	0	0	0	0	0	0	0	0
379	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0
379	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0
379	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.1	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
379	8.9	1	0	0	0	0	0	0	0	0	0	0	0	0
379	6.3	0	0	0	0	0	0	0	0	0	0	2	0	0
379	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0
379	5.7	0	0	0	0	0	0	0	0	0	0	0	0	1
379	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0
379	4.9	0	0	0	0	0	0	0	0	0	0	0	0	0
402	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
402	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
402	6.4	0	0	0	0	0	0	0	0	0	0	0	0	0
402	9.3	0	0	0	0	0	0	0	0	0	0	0	0	0
403	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0
404	15	1	2	0	0	0	1	0	0	0	1	0	0	0
404	12.6	0	0	0	1	0	1	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
404	12.5	0	1	0	0	0	0	0	0	0	0	0	0	0
404	9	0	0	0	2	0	0	0	0	0	0	1	0	0
404	14	2	1	0	0	0	2	0	0	0	0	1	0	0
404	11.2	0	0	0	0	0	0	0	0	0	3	3	0	0
404	8.5	0	1	0	0	0	0	0	0	0	0	0	1	0
404	14.1	0	2	0	2	0	1	3	0	0	2	0	1	0
404	13.8	0	0	0	0	0	1	0	0	0	0	0	0	0
404	14.1	1	2	0	2	0	0	0	0	0	0	0	0	0
404	14.8	0	2	0	4	0	1	0	0	0	0	0	0	0
404	15	1	0	0	14	0	1	0	0	0	0	0	0	0
404	20.3	1	5	0	1	0	79	1	0	0	2	0	0	0
404	16	1	0	0	2	0	1	0	0	0	1	0	0	0
404	17.6	2	0	0	1	1	28	0	0	0	0	1	0	0
404	19	3	3	0	5	5	78	0	0	0	2	0	0	0
404	20.5	2	4	0	13	1	30	0	0	0	0	0	0	0
404	19.5	5	4	0	13	3	96	1	0	0	0	0	0	0
404	17.2	0	3	0	2	0	4	0	0	0	0	0	0	0
404	15.8	0	0	0	0	0	9	0	0	0	0	0	0	0
404	15.8	0	0	0	1	0	1	0	0	0	0	0	0	0
406	6.2	0	0	0	0	0	0	0	0	0	0	0	0	0
406	8.3	0	0	0	0	0	0	0	0	0	0	0	0	1
406	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
406	9.1	0	0	0	0	0	0	0	0	0	0	0	0	1
406	9.3	0	0	0	1	0	0	0	0	0	0	0	0	1
406	9.9	0	0	0	2	0	0	0	0	0	0	0	0	0
406	10.4	0	0	0	1	0	0	0	0	0	0	0	0	0
406	11.7	0	0	0	0	0	0	0	0	0	0	0	0	0
406	12.4	0	0	0	0	0	0	0	0	0	0	0	0	1
406	12.4	0	0	0	0	0	0	0	0	0	0	0	0	0
406	13.4	0	0	0	1	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
406	15.1	0	0	0	0	0	5	0	0	0	0	0	0	0
406	15.2	0	0	0	1	0	0	0	0	0	0	0	0	0
407	8.1	0	0	0	3	0	0	0	0	0	0	0	0	0
407	11	0	0	0	0	0	4	0	0	0	0	0	0	0
413	7.2	0	0	0	0	0	0	0	0	0	0	0	0	0
417	16.2	0	0	0	0	0	13	0	0	0	39	0	0	0
417	11.5	0	2	0	0	0	0	0	0	0	2	0	0	0
417	16.2	1	0	0	0	0	22	0	0	0	10	1	4	0
417	16.7	3	1	0	0	0	18	0	0	0	7	0	12	0
417	16.8	2	0	0	0	0	5	0	0	0	16	1	0	0
420	14.1	2	1	0	0	0	1	0	0	0	5	0	4	0
420	15	6	1	0	0	1	0	0	0	0	10	0	7	0
422	10.2	0	0	0	3	0	0	0	0	0	0	0	0	0
422	10.7	2	1	0	1	0	5	0	0	0	0	0	0	0
422	10.6	3	4	0	5	0	3	0	0	0	1	0	1	0
422	10.8	5	1	0	4	0	4	0	0	0	1	0	1	0
422	10.9	2	0	0	3	0	5	0	0	0	2	0	0	0
422	11.2	6	0	1	5	0	3	0	0	0	2	0	0	0
422	11.4	14	1	0	12	0	48	0	0	0	13	0	3	0
422	12.1	5	7	0	5	0	12	0	0	0	0	0	3	0
422	12.4	1	2	0	10	0	7	0	0	0	2	0	0	0
422	12.6	2	5	1	13	0	11	0	0	0	3	0	0	0
422	12.7	2	3	1	13	0	7	0	0	0	5	0	1	0
422	13.6	10	2	0	4	0	14	0	0	0	2	0	3	0
422	13.7	15	2	0	21	0	13	0	0	0	11	0	5	0
422	14	5	4	0	17	1	5	0	0	0	6	0	5	0
422	14.4	9	4	0	19	0	2	0	0	0	6	0	1	0
422	14.8	4	4	0	21	0	27	0	0	0	3	0	3	0
422	15.3	10	5	0	10	0	48	2	0	0	12	0	7	0
425	19.3	0	0	0	1	0	21	0	0	0	4	0	6	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
427	8.9	0	2	0	0	0	0	0	0	0	0	0	0	0
428	10.3	0	1	0	0	0	0	0	0	0	3	0	0	0
429	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0
429	9.8	0	0	0	0	0	0	0	0	0	2	5	1	0
430	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
434	14.7	0	0	0	2	0	0	0	0	0	17	0	16	0
434	14.7	0	0	0	3	0	1	0	0	0	16	0	50	0
434	14	0	0	0	4	0	5	0	0	0	26	0	16	0
434	15.4	0	0	0	5	0	0	0	0	0	33	0	14	0
434	15.7	0	0	0	13	0	7	0	0	0	16	0	26	0
434	12.9	0	0	0	4	0	0	0	0	0	28	0	11	0
434	15.9	0	0	0	11	0	3	0	0	0	36	1	13	0
434	16.7	0	0	0	13	0	1	0	0	0	32	0	13	0
434	17.2	0	0	0	12	0	1	0	0	0	32	1	13	0
434	13.1	9	0	1	6	0	1	0	0	0	17	0	5	0
434	14.6	4	1	0	0	0	3	0	0	0	6	0	12	0
434	15	2	2	0	7	0	1	0	0	0	15	0	18	0
434	16.5	1	0	0	6	0	11	0	0	0	42	1	37	0
434	15.8	4	4	0	0	0	14	0	0	0	7	1	18	0
434	15.2	5	2	0	5	0	5	0	0	0	49	0	24	0
434	14.2	13	10	0	6	0	0	0	0	0	25	0	0	0
434	16.1	11	5	0	4	0	13	0	0	0	23	0	16	0
434	13.5	7	2	0	1	0	3	0	0	0	30	0	2	0
434	16.5	39	23	0	12	0	6	0	0	0	62	0	4	0
434	15.5	2	0	0	5	0	1	0	0	0	21	0	9	0
434	15.8	4	0	0	3	0	2	0	0	0	49	1	8	0
434	16.9	12	3	0	12	0	9	0	0	0	64	1	20	0
434	13.6	2	4	0	1	0	0	0	0	0	19	0	21	0
434	12.2	7	1	0	0	0	0	0	0	0	22	0	13	0
434	15.9	16	0	0	0	0	9	0	0	0	13	10	18	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
434	12.7	13	2	0	0	0	5	0	0	0	28	1	11	0
434	13	19	1	0	0	0	1	0	0	0	33	0	11	0
434	18.1	38	8	0	0	0	11	0	0	0	8	0	7	0
434	15.7	7	3	0	5	0	3	0	0	0	30	0	24	0
434	14.9	6	1	0	0	0	3	0	0	0	21	0	5	0
436	13.1	0	3	0	0	0	0	0	0	0	11	0	13	0
436	13.9	2	9	0	0	0	0	1	0	0	6	0	0	0
436	14.1	2	2	0	0	0	0	0	0	0	16	0	0	0
436	14.3	1	4	0	0	1	0	0	0	0	8	0	0	0
436	14.3	5	2	0	0	0	0	0	0	0	9	0	5	0
436	14.4	2	2	0	0	0	0	0	0	0	12	0	4	0
436	14.5	3	7	0	0	0	1	0	0	0	10	0	0	0
436	14.7	2	7	0	0	1	25	0	0	0	19	0	34	0
437	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
440	10.7	1	0	0	0	2	0	0	0	0	3	0	24	0
440	11.1	0	0	0	0	2	0	0	0	0	0	1	0	0
440	13	1	0	0	0	0	0	0	0	0	11	0	7	0
442	7.8	0	0	0	0	0	0	0	0	0	0	0	0	0
442	12.9	4	0	0	0	0	24	2	0	0	4	0	17	0
444	15.7	3	3	0	0	0	31	0	0	0	16	0	5	0
444	13.4	7	9	0	0	0	8	0	0	0	34	0	19	0
446	14.8	5	0	0	0	0	88	0	0	0	43	0	14	0
446	14.5	2	0	0	0	0	36	0	0	0	13	0	17	0
446	14.3	0	7	0	0	0	28	0	0	0	34	0	2	0
446	16.3	1	4	0	0	5	101	0	0	0	3	1	19	0
446	16	3	0	0	0	0	94	0	0	0	22	0	16	0
446	16.3	6	3	0	2	0	43	0	0	0	15	0	4	0
446	16.2	10	5	0	0	0	67	0	0	0	5	0	2	0
446	16.4	5	3	0	0	0	60	0	0	0	21	0	6	0
446	17.2	7	4	0	0	0	80	0	0	0	21	0	34	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
446	17.4	5	2	0	0	0	74	0	0	0	39	0	27	0
446	17.8	0	6	0	0	1	62	0	0	0	37	0	38	0
446	17.4	11	5	0	0	4	62	0	0	0	31	0	63	0
446	16.4	12	2	0	0	2	54	0	0	0	10	0	0	0
446	17.4	0	4	0	0	0	79	0	0	0	27	0	25	0
565	10	0	0	0	0	0	0	0	0	0	2	0	1	0
566	11.9	0	0	0	0	0	0	0	0	0	0	0	0	0
566	12.1	0	0	0	0	0	0	0	0	0	4	0	0	0
576	15.3	1	2	1	0	0	9	0	0	0	3	5	2	0
576	14.8	0	1	0	0	2	1	0	0	0	0	0	16	0
576	13.4	2	2	0	1	0	4	0	0	0	0	0	30	0
576	14.5	8	0	0	0	6	8	0	0	0	11	0	7	0
576	16.7	9	0	1	0	5	0	0	0	0	25	0	2	0
576	16.3	4	1	0	0	5	8	3	0	0	6	3	17	0
576	16.5	6	0	0	0	0	49	0	0	0	0	0	26	0
576	15.5	5	1	0	0	0	17	0	0	0	0	5	11	0
583	9.7	0	0	0	0	0	0	0	0	0	1	3	6	0
583	11.4	1	0	0	0	0	0	0	0	0	12	1	9	0
583	11.6	0	1	0	0	0	0	0	0	0	2	0	0	0
702	11	0	0	0	0	0	0	0	0	0	0	0	0	0
702	14.5	1	1	0	0	0	0	0	0	0	53	0	0	0
702	14	0	0	0	0	0	0	0	0	0	33	0	34	0
702	9.5	0	0	0	0	0	0	0	0	0	1	1	1	0
702	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0
702	8.6	0	0	0	0	0	0	0	0	0	4	0	0	0
702	17.7	0	1	0	0	0	22	0	0	0	9	5	0	0
716	9.1	0	0	0	0	0	0	0	0	0	0	0	0	0
716	10.9	0	0	0	0	0	1	0	0	0	3	0	0	0
716	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0
716	11.4	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
716	11.9	0	0	0	1	0	0	0	0	0	4	0	1	0
716	12.1	0	0	0	0	0	0	0	0	0	6	0	0	0
716	12.5	1	0	0	0	0	0	0	0	0	9	0	2	0
716	12.7	0	0	0	0	0	0	0	0	0	0	0	0	0
716	12.7	0	0	0	0	0	1	0	0	0	1	0	0	0
716	12.7	1	0	0	0	0	1	0	0	0	0	0	0	0
716	13.2	2	0	0	0	0	0	0	0	0	5	0	0	0
716	13	0	0	0	0	0	0	0	0	0	0	0	0	0
716	12.8	1	0	0	0	0	0	0	0	0	2	0	0	0
716	13.3	1	0	0	0	0	4	0	0	0	2	0	0	0
716	13.5	3	0	0	0	0	3	0	0	0	5	0	0	0
716	13.7	2	0	0	0	0	0	0	0	0	11	0	0	0
716	13.7	0	0	0	0	0	1	0	0	0	0	0	1	0
716	13.7	2	0	0	0	0	3	0	0	0	5	0	0	0
716	13.8	0	0	0	0	0	4	0	0	0	0	0	0	0
716	14.9	1	0	0	0	0	0	0	0	0	5	0	0	0
716	15.1	0	1	0	0	0	17	0	0	0	10	0	0	0
716	15.3	2	0	0	0	0	9	0	0	0	6	0	0	0
716	15.6	0	0	0	0	0	2	0	0	0	4	0	0	0
716	10.8	0	0	0	0	0	1	0	0	0	0	0	0	0
716	12.3	1	0	0	0	0	2	0	0	0	3	0	0	0
722	15.2	0	0	0	0	0	1	0	0	0	1	0	2	0
722	14.5	2	0	0	0	0	0	0	0	0	4	0	0	0
722	14.1	3	0	0	0	0	1	0	0	0	12	0	0	0
722	14.5	1	0	0	0	0	1	0	0	0	5	0	0	0
722	14.6	2	0	0	0	0	1	0	0	0	10	0	0	0
722	14	1	0	0	0	0	0	0	0	0	7	0	0	0
722	14.1	1	0	0	0	1	0	0	0	0	9	0	0	0
722	14.2	2	0	0	0	0	0	0	0	0	3	1	0	20
722	15.4	1	2	0	0	0	12	0	0	0	16	5	0	0

Table A.5 continued. Prey identification and number of prey items for individual alewife larvae fixed in 10% buffered formalin.

trapID	TL	Halicyclops	D. thomasi	E. affinis	UK cop	Daphnia	B. freyii	L. kinditii	UK Bosmina	Diaphanosoma	nauplius	rotifer	veliger	UK
722	13.5	0	0	0	0	0	7	0	0	0	9	1	2	0
722	12.4	0	0	0	2	0	0	0	0	0	6	3	0	0
722	14.6	0	0	0	1	0	5	0	0	0	14	3	0	0
722	13.8	2	1	0	0	0	0	1	0	0	10	4	0	0
722	15.5	1	1	0	0	0	0	0	0	0	15	0	0	0
722	14.6	1	1	0	1	0	1	1	0	0	11	0	2	0
722	14.4	2	0	0	0	0	0	0	0	0	18	0	0	0
722	14.3	0	0	0	0	0	0	0	0	0	4	0	0	0
722	13.1	0	0	0	0	0	0	0	0	0	0	0	0	0
722	12.9	3	0	0	1	0	0	0	0	0	5	0	0	0
722	12.5	0	0	0	0	0	0	0	0	0	6	0	0	0
722	12.3	2	2	0	0	0	0	0	0	0	20	0	3	0
722	13	7	0	0	0	1	1	0	0	0	9	0	0	0
722	13.9	0	3	0	0	0	0	0	0	0	28	0	0	0
722	14.1	2	0	0	0	0	0	0	0	2	4	0	0	0
722	14.4	0	0	0	7	0	0	0	0	0	11	2	0	0
724	9.9	1	0	0	0	0	0	0	0	0	4	1	0	0
737	12.8	1	1	0	0	0	7	0	0	0	12	0	0	0
737	12.8	1	1	0	0	0	1	0	0	0	4	0	0	0
737	12.6	0	0	0	0	0	1	0	0	0	9	0	3	0
737	14.7	1	5	0	0	0	6	2	0	0	5	0	15	0
737	9	0	0	0	0	0	0	0	0	0	0	0	0	0
737	11.2	1	0	0	1	0	0	0	0	0	2	0	0	0
737	13.1	1	0	0	0	0	0	0	0	0	0	0	0	0
737	8.8	1	0	0	0	0	0	0	0	0	6	0	0	0
746	10.5	0	0	0	0	0	0	0	0	0	2	0	2	0

Table A.6. Total length, age, body measurements, and gut state for the individual alewife larvae preserved in 90% ethanol.

NumID	age	TL	SL	head	PBD	ABD	gut
434	24	19.8	17.1	1.2	1.6	1	1
434	22	18.1	15.8	1.1	1.5	0.7	1
434	25	16.7	14.7	0.9	1.1	0.6	1
434	22	17.2	15.2	1.2	1.3	0.8	1
434	22	16.5	15	1	1.1	0.7	1
434	22	15.7	14	0.9	0.9	0.5	1
434	21	15.8	14.6	1	1.1	0.6	1
434	23	16.7	14.9	0.9	1.2	0.7	1
434	23	15.3	14	0.9	0.9	0.5	1
434	21	15.8	13.9	1	1.1	0.7	1
434	23	12.8	12.3	0.8	0.6	0.4	1
434	20	13.5	12.6	0.8	0.8	0.3	1
434	20	14.9	13.8	0.9	0.8	0.5	1
434	25	19	16.6	1.3	1.6	1	1
434	26	15.8	14.3	0.9	1	0.6	1
434	24	14.1	12.8	0.9	0.9	0.5	1
434	23	15.3	14	1	1	0.5	1
434	25	16.5	14.9	1	1.2	0.7	1
404	12	10	9.7		0.5	0.2	0
404	19	16.8	15.5		1	0.8	0
404	18	14	13.1		1	0.7	0
404	19	18.8	16.5		1.6	1.2	1
404	17	16.1	14.5		0.8	0.6	1
404	18	18.5	16.2		1.3	0.9	1
436	17	13.8	12.8	1	0.9	0.5	1
436	18	10.7	10.5	0.7	0.5	0.3	1
436	15	10	9.8	0.6	0.5	0.2	1
436	17	12.6	11.9	0.8	0.6	0.3	1
436	19	13.5	12.4	0.7	0.6	0.4	1
404	21	16.4	14.9	0.8	0.9	0.6	1
404	18	15.6	14.3	1	1	0.5	0
404	16	15.7	14.5	0.8	1	0.6	0
404	16	15.9	14.4	1	0.8	0.6	1
404	13	10.1	9.8	0.7	0.5	0.2	0
404	13	10.3	10	0.5	0.5	0.2	0
404	16	16.2	14.6	0.9	1.1	0.6	1
404	19	18.5	16.1	1.3	1.5	0.9	1
404	19	16.4	14.9	1	1	0.7	1
404	17	14.4	13	0.9	0.9	0.6	1
407	10	7.2	7.2	0.3	0.3	0.1	0
407	17	16.3	15.2	0.9	0.8	0.6	1

Table A.6 continued. Total length, age, body measurements, and gut state for the individual alewife larvae preserved in 90% ethanol.

NumID	age	TL	SL	head	PBD	ABD	gut
407	15	12.3	11.7	0.8	0.5	0.3	0
410	14	12.9	12.5	0.7	0.6	0.3	0
410	11	9.1	8.8	0.6	0.5	0.3	0
410	14	12.1	11.5	0.7	0.6	0.3	1
410	16	11.8	11.3	0.7	0.6	0.4	1
410	13	13.7	12.6	0.8	0.7	0.4	1
410	14	14.2	13.2	0.9	0.6	0.4	0
410	17	14.8	13.4	0.9	0.7	0.5	1
410	13	11.1	10.8	0.5	0.4	0.2	0
410	15	12.8	12.1	0.8	0.7	0.4	0
410	12	10.3	9.8	0.6	0.4	0.2	0
410	11	8.5	8.5	0.6	0.5	0.2	0
410	16	12.9	12.3	0.7	0.7	0.4	0
410	13	11.5	11.3	0.8	0.5	0.2	0
410	13	11.9	11.4	0.7	0.6	0.2	0
410	17	15.3	13.8	1	0.8	0.5	1
410	13	10.1	10.1	0.5	0.4	0.2	0
410	15	11.6	10.9	0.8	0.5	0.3	0
410	12	9.8	9.8	0.5	0.4	0.2	0
410	16	11.6	10.8	0.6	0.5	0.3	0
410	9	10.6	10.3	0.6	0.4	0.3	0
410	16	14.8	13.6	0.8	0.7	0.4	0
410	10	9.6	9.5	0.7	0.5	0.2	0
410	12	12.1	11.6	0.6	0.7	0.3	0
410	16	12.2	11.5	0.7	0.6	0.3	0
410	15	10.5	10.3	0.6	0.6	0.3	0
719	13	8.9	8.9	0.4	0.2	0.1	0
719	16	14.5	13.5	0.9	0.6	0.4	1
583	18	12.1	11.8	0.8	0.6	0.4	1
583	21	12.7	12	0.8	0.7	0.3	1
583	19	10.4	10.2	0.7	0.4	0.2	1
583	16	13.1	12.2	0.8	0.7	0.3	1
583	21	13.2	12.4	0.8	0.7	0.4	1
583	18	12.2	11.9	0.9	0.6	0.3	1
583	18	12.3	11.7	0.8	0.6	0.4	1
583	20	11.8	11.3	0.8	0.6	0.4	1
583	21	13.4	12.3	0.9	0.7	0.4	1
583	20	14.4	13.6	0.9	0.9	0.5	1
583	18	13	12.2	0.8	0.7	0.3	1
583	20	12	11.3	0.8	0.6	0.4	1
583	20	12.5	11.8	0.9	0.8	0.4	1

Table A.6 continued. Total length, age, body measurements, and gut state for the individual alewife larvae preserved in 90% ethanol.

NumID	age	TL	SL	head	PBD	ABD	gut
583	17	11.4	11.2	0.8	0.6	0.4	1
583	18	12.3	11.5	0.8	0.6	0.3	1
583	15	12.1	11.7	0.8	0.5	0.3	1
716	18	14.6	13.6	0.9	0.7	0.5	1
716	16	13.7	12.7	0.8	0.8	0.4	1
716	14	13.5	12.6	0.8	0.7	0.4	1
716	14	15.1	13.9	0.9	0.8	0.6	1
716	15	14.6	13.5	0.9	0.9	0.5	1
716	15	14.8	13.5	1	1	0.5	0
716	15	13.6	12.7	0.7	0.7	0.4	1
716	16	14.1	13.2	0.8	0.7	0.4	1
716	14	13.9	12.8	0.8	0.8	0.4	1
716	18	16.4	14.9	1	1	0.6	1
716	18	15.5	14.6	0.9	1	0.6	1
716	14	12.7	12.1	0.7	0.7	0.4	1
716	17	12.3	11.5	0.9	0.6	0.4	0
716	19	15.8	14.4	1	1.1	0.6	1
716	19	14.6	13.6	0.9	0.8	0.5	0
556	18	16.9	14.9	0.9	1.2	0.6	1
556	22	18.7	16	1.2	1.4	0.7	1
556	20	18.2	16.1	1.1	1.2	0.8	1
556	17	17.2	15.6	1	1.2	0.8	1
556	18	16.7	14.8	1.1	1	0.7	1
556	19	17.4	15.6	1.2	1.3	0.7	1
556	19	16.4	14.9	0.9	0.9	0.5	0
425	24	18.3	16.2	1.2	1.6	0.9	1
425	25	18.6	16.3	1.2	1.6	1	1
425	23	18.9	16.4	1.2	1.4	1	1
425	23	18.5	16.8	1.2	1.7	1.1	1
425	22	18	15.9	1.1	1.4	0.9	1
425	25	19.6	17.3	1.3	1.6	1.2	1
425	22	17.8	15.8	1.1	1.4	0.8	1
425	23	19.5	17.3	1.2	1.8	1.2	1
425	22	19	16	1.3	1.7	0.9	1
425	27	20.1	17.4	1.3	1.7	1.3	1
425	24	19.8	17.2	1.4	1.9	1.3	1
425	20	16.6	15	1	0.9	0.7	1
425	23	18.8	16.3	1.2	1.6	1	1
425	24	19.8	17.2	1.4	1.8	1.3	1
425	27	19.4	16.4	1.2	1.7	1.1	1
425	21	17.1	15.6	1.2	1.3	0.9	1

Table A.6 continued. Total length, age, body measurements, and gut state for the individual alewife larvae preserved in 90% ethanol.

NumID	age	TL	SL	head	PBD	ABD	gut
425	24	20.1	17.8	1.2	2	1.2	1
425	26	20.1	17.3	1.2	1.9	1.2	1
425	22	19.8	17.1	1.3	1.7	1.1	1
425	23	19.3	16.3	1.4	1.6	1.1	1
722	17	15.5	14	0.9	1.2	0.8	1
722	20	15.3	13.7	0.9	1.1	0.6	0
722	18	15.2	13.6	1	1	0.5	0
722	20	15.9	14.4	1.1	1	0.7	1
722	17	13.6	12.6	0.9	0.9	0.5	0
722	18	15.3	14.1	0.9	1	0.6	1
722	19	14.8	13.5	1	0.9	0.4	0
722	22	15.8	14	1	0.9	0.6	0
722	23	14.8	13.6	0.9	0.9	0.7	0
722	19	14.9	13.4	1	0.9	0.5	0
722	21	16.2	14.5	1.1	1.2	0.8	0